Nurserymen's Meeting
Kemptville
June, 1983

Ontario

Ministry of
Natural
Resources

Hon. Alan W. Pope
Minister

John R. Sloan
Deputy Minister

ERRATA

On p. 12, second-last paragraph, second-last line " the lining materials" should read "the liming materials".

On p. 32, last line: "root centres" should read "cost centres".

On pp. 58 and 60, the second column from the right should be headed "Dry Weight (g)" not "Dry Weight (gm)". Also, on p. 58, under RA1 (cm^2) at o.5N, "34.46 bcd" should read "36.46 bcd".

On p. 61, under the "Treatment" heading of the top two sections, "in" refers to "inches".

On p. 64, second-last line, "a systemtic problem" should read "a systemic problem".

On p. 76, the fourth line from the bottom, "per twelve thousand" should read "per thousand".

On p. 77, this sentence should be added after the second line "In addition to the regular rate, the contracts provide for an excess rate which is applied in the purchase of seedlings produced by the grower in excess of the annual production target.

On p. 80, last paragraph, second line, "contained" should read "contain".

On p. 81, throughout the first two paragraphs, "dessication" should read "desiccation". Also, on p. 81, the fifth line from the top, "if there a thaw" should read "if there is a thaw".

On p. 83, second-last paragraph, first line, "growing media-white spruce and pregermination" should read "growing media and white spruce pregermination".

On p. 90, second full paragraph, second line, "data calculation" should read "data collection".

On p. 93, fifth-last line, "frequenty" should read "frequency".

On p. 96, under 1 Hour at 23.62C, "6.30" should read "7.30".

On p. 107, third paragraph, first line, "Quantity evaluations" should read "Quality evaluations".

On p. 111, last paragraph, first line, "growth performance and nutrient levels" should read "growth performance, pH and nutrient levels".

On p. 120, sixth line, "nursery" should read "nurseries".

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I

HYBRID POPLAR: FAST-GROWING HARDWOODS

Alf Campbell

About 1970, Dr. Louis Zsuffa of the Tree Breeding Unit, Ontario Tree Improvement and Forest Biomass Institute, Ministry of Natural Resources, established hybrid poplar stool beds (cutting beds) at the G. Howard Ferguson Forest Station. Over the next six years, very few cultural practices and little developmental work was carried out; hence, cuttings were produced at a rate of only three to five per stool bed. The low production figures reflected the low priority given to the hybrid poplar programme at that time. In 1977, however, the programme was given priority; hence, development of cultural practices began, production rose to eight cuttings per stool, and new stool beds were established.

In 1978, a Department of Regional and Economic Expansion (DREE) agreement entitled New Forests was signed between Canada and Ontario. During that year, approximately 17 ha of land were cleared. At the same time stool beds were expanded, so that in the fall there were 900 000 unrooted cuttings produced. (Note the rapidity of increase in unrooted cutting production compared with that of bare-root production.)

Challenges

There were many challenges to be met with the increase in production. First, little was known about fertility and irrigation regimes. Soils were researched, with the help of Vic Sadreika, to determine suitable chemical compositions for top dressings.

After two years, we arrived at a solution: to divide 200 kg/ha of ammonium nitrate into 8 to 12 applications, depending on climatic factors, the final application to be made on July 15. In addition, 112 kg/ha of monoammonium phosphate would be applied in the second and subsequent years before bud break. In order to maintain balance and aid hardening off, a total of 170 kg/ha of potassium sulfate would be applied in three treatments.

Although irrigation problems are still unresolved, we have successfully varied the volume of water from 1.5 cm every two days to 2.5 cm every four days. However, further development work is needed in this area.

Handling an increased number of clones and maintaining clonal integrity has meant a change in stool bed conformation. Currently, each clone is in a block that is surrounded by a 2.7 m to 3.5 m break. Within each block there are 21 rows, each row spaced 90 cm apart for convenience of tractor work. An 8.3 m width is ideal for two passes of an hydraulic sprayer and the throw of our irrigation system. Each block is identified by four aluminum stacks which are further identified with a riveted clone plate.

Where adequate cutting material is available, a stool bed is established using 25 cm unrooted cuttings, except in the care of aspen-type clones where rooted cuttings are used. These are usually planted with a narrow trencher tree planter. When cutting material of a new and desirable clone is in short supply, we use a method known as the mini-cutting process. In this process, small 7.5 cm cuttings are planted in Japanese paperpots and placed in a greenhouse. In about three weeks the rootings will have occurred. After a short hardening period the cuttings are then planted by hand in the stool bed conformation. Although better stocking is achieved with this method, it is approximately five times as expensive.

With more cuttings being produced, greater efficiency in harvesting had to be achieved. Therefore we reduced the number of handlings of whips and storage of whips. At the Maple offices, Tony Citro developed an excellent pneumatic cutting head, which set the pace for the whole operation. (Details of this system are available in the Shipping Centre.)

The final challenge was, and still is, to match hybrid poplar in general to the proper compartment soils. We know that poplar should be on a soil with a pH level ranging from 6.5 to 7.5. The soil must be as high in organic matter as possible; currently we are aiming at five per cent.

Problems and Solutions

When intensive culture was begun on hybrid poplar, it created new stresses which manifested themselves in several ways.

The first major problem was frost damage in mid-September. By pushing hybrid poplar growth with high amounts of nitrogen and water, we obtained a height growth of 2.4 to 4.3 m in the year. However, we had a succulent growth which did not harden sufficiently to withstand frost in mid-September. In order to overcome this problem, the number of applications of nitrogen in the fertility regime was reduced. The final application is now scheduled for no later than July 15. In general, this regime is successful unless a temperature of lower than -4° is reached.

As cultural activities have increased, so have the tending problems. Applying herbicides to control a growing weed population should be done slowly and cautiously because of poplar sensitivity. An overspray of Roundup (glyphosate) before bud emergence in spring should be carried out, but only if grass has invaded the stool area. Hand rototilling and weeding is stabilized with an application of Devrinol. (Although this herbicide is still not licenced in Canada, we have permission to use it in production trials.) For a further breakthrough of weeds, again rototill; usually, by this time, the stools will have closed crowns and have captured the site for the year. Some testing will be required to make certain that chemicals are not contributing to frost susceptibility and late stool finishing.

Insects have a tremendously concentrated growth on which to establish populations. Because insect problems can occur so quickly, it has been necessary to adopt a prophylactic treatment of the insecticide Malathion every seven days. The injection into the soil of Furidan, a systemic, did not seem to provide adequate protection.

There remain two problems with only partial answers. First, the erratic hybrid poplar growth of 50 cm compared to 4 m in some compartments has been studied from a nutrient standpoint, but this study has been unsuccessful. Although a new tactic is being pursued through the study of soil mechanics, i.e., compaction, it is too early to determine the results of the subsoiling tests.

Second, the late sprouting of hybrid poplar in the third year of a stool bed seems to have many avenues of study still open. Solutions may lie in spacing, nutrients, chemical herbicides, irrigation, and time of harvesting. Presently we hope to encourage research institutions and universities to help us resolve these problems.

Achievements

- A production level has been reached that is satisfying field technology development demands.
- A system of survival and historical data records has been developed.
- The mini-cutting greenhouse procedure has been refined to a consistently predictable level.
- The quality and integrity of clonal unrooted cuttings have been improved.
- Harvesting operation efficiency has been improved, thus reducing costs from 15¢ to 6¢ per cutting.

Present Status — 1982

- 1.6 million unrooted cuttings were produced, along with research activities, stool bed expansion, and Carolina poplar production.
- 114 clones were in production in the fall.
- There are 236 clones on the station, which includes those in the clone bank.
- 20.5 ha of land, which includes the Carolina poplar beds, are in production.
- Approximately 50 000 cuttings were planted and rooted, then shipped as 1+0 rooted stock. (The same growing procedures were applied as to unrooted stock.)
- 100 000 hybrid poplar progeny and other species such as alder and birch were produced for field planting in the fast-growing hardwood programme.
- 34 willow clones were grown in small production blocks similar to hybrid poplar.

Table I-1: Cutting stock specifications

	Cutting Type		
Characteristics	Production Cutting	Mini Cutting	Greenwood Cutting
Physiological conditions	Dormant	Dormant	Actively growing
Storage conditions	Frozen -3°C	Frozen -3°C	Perishable: must be kept actively growing
Size: Length	25 cm	7.5 cm	Variable
Diameter	10 - 20 mm	n/a	Variable
Use	Production planting	Rapid propagation of valuable genetic material available in very limited amounts	Propagation of special genetic stock, i.e. plus-trees, rare clones, propagation of poor-rooting genetic material

Table I-2: Tending schedule at Kemptville nursery

Activity	Total Rate for Growing Season	Comments
Fertilizer		
Ammonium nitrate	200 kg	Several applications by irrigation system, ending late June
Potassium sulphate	170 kg	Three applications by agricultural fertilizer spreader, ending mid-July
Monoammonium phosphate	112 kg	Apply in second year before bud break
Weed control		
Herbicide:		
Enide* + Dacthal†	9.8 kg + 9.8 kg	Boom spray by mid-May
Roundup#	2.2 kg	Before stool leaf flush (grass control)
Manual weeding	n/a	Throughout the growing season
Pest control		
Malathion	1.4 L	Prophylactic treatment every 1 to 2 weeks (boom spray)
Irrigation	1.5 - 2.0 cm irrigation every 3 to 4 days	Maintain compartments between field capacity and one bar matrix tension (none after late July)

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* Enide is a trademark for diphenamid manufactured by Upjohn.

† Dacthal is a trademark for D.C.P.A. manufactured by Diamond Shamrock.

# Roundup is a trademark for glyphosate manufactured by Monsanto.

Table I-3: Cultural practices for 1+0 and 2+0 production at Kemptville nursery

Activity	1+0 Production	2+0 Production
Site preparation	Same as cutting production	Same as cutting production
Planting:		
Planting stock	Unrooted cuttings	Unrooted cuttings
Spacing	1 m x 10 cm	1 m x 50 cm
Block size	One line marked at both ends	One line marked at both ends
Tending:		
Fertilizer	Same as cutting production	Same as cutting production
Weed control	Same as cutting production	First year — same as cuttings; second year — manual and rototiller
Pest control	Same as cutting production	Same as cutting production
Irrigation	Same as cutting production	Same as cutting production
Pruning	Not required	Prune lower half of stem in late summer of second year; prune all remaining branches in the fall of second year
Lifting	Spring (Egedal lifter)	Spring (Egedal lifter)
Shipping	Spring	Spring

II

HYBRID POPLAR PRODUCTION: HARVESTING, PROCESSING, SHIPPING, AND STORAGE

Pamela A. Smith

Poplar processing, from beginning to end, is an assembly line process. It is divided into two sectors: field harvesting and shed processing.

The processing starts with the field harvesting, which is the cutting of the poplar into whip form. This process starts as soon as lignification has taken place, usually towards the end of October into mid-November. The whips are cut as close to the base of the stool as possible and they are graded, leaving the small and damaged ones in the field. The whips to be cut are tied in bundles, tagged, and delivered in bulk to the shed by truck.

The field harvest cutting is done by hand using long-handled shears. Other methods such as pneumatic shears and hydraulic shears have been tried, and while the hydraulic shears proved to be slower and cumbersome, the pneumatic shears worked well and have some potential.

Approximately 110 clones are being harvested for cutting production at present, and all harvesting and cutting processes are done by clone and compartment. In this way statistics can be accumulated on production yield by age-class. This is especially helpful for both projecting cutting inventories and setting up loss-survival records.

The shed processing is divided into several different phases: (i) pruning of whips; (ii) cutting, grading, and counting of cuttings; and (iii) packing, painting, and storage.

When the whips are delivered to the shed, the clone and compartment are recorded and whips are put aside for pruning. All pruning of the lateral branches is done by hand. Until last season, the pruning operation was completed in the shed area. Last season we experimented by moving the operation to an empty supply building or an empty greenhouse. The greenhouse proved a favourable location: it has a completely different atmosphere, away from the noise; it has better lighting; and in general this rather humdrum operation becomes much more pleasant. Also, it moves most of the congestion away from the shed area.

Once pruned and recorded as such, the whips — which have also been sorted according to size, tagged, and rebundled — are moved up to the knife area for cutting.

The pneumatic knife or knives are mounted on the belt in such a manner that one is fed from the right-hand side and one from the left-hand side. The air pressure is supplied by the Hydrovane Air Compressor, which produces approximately 1.82 m^3 of air per minute. There is a constant pressure of 45 kg at the knife. The blade is not vertical but drops at an angle, thus increasing the pressure slightly and creating a slicing effect rather than a blunt chop. The arm's length has an adjustable play of 5 to 25 cm. (We require this adjustment because we produce 6, 15 and 25 cm cuttings, for greenhouse production, for Carolina poplar production, and for regular stool expansion, property plantings, etc., respectively.) The knife accommodates 3.1 mm diameters. Our grade diameter factors are: 6-10 mm for small; 11-20 mm for medium; and 21+ mm for large. Mainly medium and large knives are used; however, small ones are used where the clonal material is in short supply.

Whips are put through the knife in bundles of three to six, depending on the whips' diameters; these vary from clone to clone. The butt ends of the whips are always put through first, and only the lignified portions of the whips are used. Most buds, therefore, are running in the same direction when the cuttings drop to the belt.

Graders remove the cuttings from the belt, grade them according to size and quality, and place them in tubs, maintaining the uniformity of bud direction. Damaged or crooked cuttings are left on the belt for disposal, as are small cuttings unless specifically required.

The tubs of cuttings are removed to the table area, where they are counted, graded a second time, and made into bundles of 25 which are secured by elastic and passed down the line to the packing area. The packer checks the bundles for grade, bud, and number, and puts them in boxes. A box will usually contain 250 or 500 cuttings, depending on the size of the cuttings. (We pack in these denominations because cutting allocations are designed in these numbers; it saves considerable time on re-packing and handling the cuttings.) During the past year 3200 boxes were packed.

The boxes are wax-cascaded and have a 4 ml weight plastic liner. (Heavy bags should be used, especially in the field when planting.) Once packed, the boxes are passed to the painting area, where the top ends are coloured with a red water-based latex. The painting serves three purposes: it identifies which end is up for planting; it allows easy finding in the planted area; and it prevents desiccation.

The bag is tied; labelled with such particulars as quantity, clone, and compartment; and then strapped shut by an automatic stripping machine, which eliminates the use of staples. The strapped, labelled box is put on a pallet for frozen storage. (A lift holds 32 boxes.) A record of the storage area is kept, which allows quick retrieval at the time of repacking.

Cuttings are kept in frozen storage until February or March at -3.3°C, optimum. Although the temperature may fluctuate by ±1°C, any temperature colder than -4.5°C or warmer than -2.2°C will cause freezer burn or sprouting, respectively.

The frozen cuttings are shipped in bulk by tractor trailer. Allocations are received by mid-February to mid-March. The boxes are sorted and labels marked with their destinations; the labels provide district and property details.

Next season cuttings will be sorted into clones before shipping. For example, if Cornwall is to get 5000 of clone DN 1, then they will receive 10 boxes of 500 cuttings; the property and plot will not be noted.

The whole operation, weather permitting, can be done within 12 to 15 days. We start with a staff of approximately 85, which decreases as the volume of work declines. About 15 to 16 staff are in the field; 40 to 45 are pruning; and the remainder are distributed over the belt (6 to 8), the table (8 to 10), and in the packing, painting, and storage areas (5 staff).

Our total production is between 1 million and 1.3 million cuttings at present. Our daily production ranges from 80 000 to 106 000 cuttings, depending on the size of the clones. As a smaller quantity of clones takes more time to assemble, thus requiring more shut-down time, production is much less. Recently, modifications have been made to the system to lessen the time shut down; in the future we hope to set up two separate belts and gain further improvement.

Currently, for example, when the production of one clone ends, one table completes the counting while the belt and a second table begins production of another clone. The second clone is held from the packing and painting area until the first is completely packaged. Large quantities present no difficulties here; dealing with a series of small quantities, however, can be difficult and time-consuming.

Finally, as in any assembly-line operation, each phase depends on every other; if one phase gets out of step, production is backed up all the way down the line. If the field gets ahead of the pruners in the shed, we end up with congestion and an overload of whips; if the field gets behind, we end up with staff who have nothing to do. There are two ways to manage this: we may modify the placement of our staff, moving people from one phase to another to speed up a particular operation; or we may switch to a lighter- or heavier-branched clone (which will, respectively, speed up or slow down the pruning operation). Our goal is always to keep the pace as even and efficient as possible.

III

LIMING, SOIL pH, AND HYBRID POPLAR GROWTH

V.R. Timmer

The pH requirements of nursery soils used in the production of hardwoods are generally higher than those of softwoods. Individual species differ in their tolerance to soil acidity and alkalinity. For most coniferous growing stock, pH values of 5.0 to 5.5 seem desirable (Armson and Sadreika, 1979; van den Driessche, 1976); on the other hand, a pH range between 6.0 and 6.5 is considered satisfactory for hardwood seedlings (Williams and Sidney, 1976). To a large extent soil pH regulates the solubility and availability of several important nutrient elements and controls decomposition and microbial processes in soils. Seedlings may grow over a relatively wide range of pH values as long as the supply and availability of nutrients are adequately and properly maintained. Thus, it is important to monitor soil reaction and soil nutrient status routinely, so that adjustments can be made promptly to maintain the soil as closely as possible to optimum levels.

The modification of soil pH for plant growth requires a basic knowledge of soil reaction and its relationship to nursery crop culture. In Ontario this type of information is available for coniferous nursery stock production (Armson and Sadreika, 1979); equivalent data for deciduous species, however, is scarce. The recent demand for increased production of hardwood stock, especially for the hybrid poplar programme in Eastern Ontario, has stimulated greater interest in this topic and has prompted the Ministry of Natural Resources to initiate studies in the pH requirements of hybrid poplar in nursery culture.

Liming to Raise Soil pH

Most practices relating to soil pH adjustment in nurseries involved lowering pH values (acidification). Considerable experience has been gained in this field. Mullin's (1964) work has provided the necessary data base for developing reliable prescriptions for applying sulphur to acidify nursery soils. In contrast, the need for liming has not occurred frequently in the Ontario tree nurseries. Starting in 1979, preliminary efforts at raising soil pH were undertaken at the Kemptville nursery. Early trials involved the use of agricultural limestone supplied by the CIL company as ground dolomite. The outcome of a preliminary field trial proved disappointing, since soil pH levels, after one season, did not change markedly despite dosage rates of 500 to 3000 kg of limestone/ha (Table III-1). A trial in the following year, using increased replication as well as proper control treatments, tested the same material at even higher application rates but also failed to demonstrate significant increases in soil pH values at the end of a single growing season (Table III-1).

The results suggested that (i) the soils were highly buffered to neutralization processes, and (ii) the limestone used in these treatments was particularly unreactive. These factors were tested in the laboratory. Buffer curves of the Kemptville soil were compared with the Thunder Bay nursery soil, which was known to be poorly buffered (Armson and Sadreika, 1979). The curves (Fig. III-1) showed indeed that the Kemptville soil had a considerably higher buffering capacity than the Thunder Bay soil, especially on the basic side. This would explain the necessity of using higher than normal rates of application for the soils at Kemptville.

It is well known, however, that the effectiveness of limestone in raising pH is highly dependent on the fineness of the material and its chemical composition. These properties influence the rate of dissolution and reaction of lime with the soil. Mechanical screening of the CIL material revealed it was a coarse grade dolomite, with 64% of the grains passing through a 10 mesh screen, while only 2% passed through a 100 mesh screen. Chemical analysis of the lime also indicated low levels of calcium (Ca) (32%) and magnesium (Mg) (5%), with a neutralization value of 103%. This grade of limestone would probably be effective in raising soil pH over the long term, but was too coarse to cause immediate increases in soil pH, as was desired in these trials.

The importance of particle size in liming is illustrated in Fig. III-2, which shows the pH development of limed Kemptville soils under laboratory incubation at 30°C. The CIL limestone was added at an equivalent rate of 8000 kg/ha at three different mesh sizes. The finer sized (100 mesh) material exhibited the most rapid reaction rates, causing a much earlier and larger rise in pH than the coarser grades of the same limestone. The incubated soil samples were irrigated daily with 0.8 cm of water to simulate field conditions. Leachates were collected weekly and tested for Ca and Mg. Compared to the coarse grade lime, the finer material was associated with earlier and higher peak concentrations of these elements in the soil solution (Fig. III-3). Although the lining materials were of the same chemical composition, the finer grade displayed increased solubility and reaction rate in the soil.

An alternate source of limestone from a local contractor was then obtained for nursery use. This was a pulverized source (100% passing 100 mesh size) which rated a neutralizing value of 135%, and contained 45% Ca and 7% Mg. Its responsiveness in the soil was evaluated against the CIL lime in a subsequent incubation experiment. The materials were added at similar (8000 kg/ha) rates in screened and unscreened forms. As can be seen in Fig. III-4, the contractor's lime, incorporated at similar dosages and mesh size, was far superior to the CIL limestone in elevating soil pH values. Without sieving, the latter managed to raise pH levels only slightly above those of the control soil, reflecting typical responses from the field trials. The commercial limestone obtained from the contractor was subsequently field tested at comparable rates in nursery beds (Table III-1). The results confirmed the laboratory tests that the liming material obtained from the local contractor was much more efficient than the CIL lime in adjusting pH upwards.

The findings from these studies underscore the validity of rating liming materials for nursery application by chemical composition as well as particle size. The neutralization value of limestone can be determined rapidly in the laboratory, and seems to be a sensitive index of its effectiveness in nursery application. We recommend that this type of analysis be conducted routinely on liming materials used in nursery soil management.

pH Requirements for Hybrid Poplar Culture

Another objective of our studies was to determine the optimum pH levels for the growth of hybrid poplar in stool beds. These requirements may vary with the type of hybrid. The approach was to grow different clones over a wide range of soil acidity. The trials were laid out with four replications in a newly established compartment (No. 84) in the Kemptville nursery. The soils were adjusted to six contrasting pH levels (treatments) by acidification with sulphur (at 2 t/ha and 5 t/ha over two years) and by neutralization with limestone (at 7.5, 15, and 30 t/ha over two years). More than 20 different clones were planted at the beginning of the growing season. The experiment was duplicated under more controlled conditions in a pot trial at the Glendon Hall greenhouse using the identical soil at similar pH levels, but testing only two clones (DTAC 32 and DN 12) because of space constraints. Unfortunately, the trees in the test compartment were subject to repeated deer browsing over the summer, thus confounding height measurement and masking actual treatment effects. Although soil reaction at the end of the season indicated that a broad range of pH (4.5 to 7.9) had been obtained, the growth response of the trees could not be reliably assessed.

The greenhouse trial was completed. By fall, soil pH of the pots ranged between 4.1 and 7.6, which corresponded well with the values attained in the field trial. Growth differences due to treatment occurred early in the trial. Both clones were sensitive to acid conditions, DN 21 somewhat more so than DTAC 32. The three trees of clone DN 21 that received the largest application of sulphur died by mid-season, presumably because of high soil acidity. Hence, only data of clone DTAC 32 will be discussed here.

Maximum height growth of DTAC 32 over the 20-week growing period occurred at a pH of about 6.5, which was 70% higher than that obtained at a pH of 4.1 (Fig. III-5). Soils of the control treatments ranged between 5.9 and 6.1. The liming treatments raised soil pH significantly, but improved shoot development only marginally. The sulphur treatments had reduced tree growth and soil pH significantly.

Compared to other commercial tree species, hybrid poplar has been shown to be extremely sensitive to high concentrations of aluminum (Al) in nutrient solutions (McCormick and Steiner, 1978). Chemical analyses of the plants and soils were undertaken to determine whether the reduction in growth was associated with increased plant-available Al in soil. Both calcium chloride ($CaCl_2$) — extractable Al in the soil — and Al levels in the leaves increased sharply with decline in soil pH (Fig. III-6), indicating that Al availability was increased by the sulphur applications. Height growth of the trees was also linearly and inversely related to soil Al ($r=-0.92$) and foliar Al ($r=-0.91$), suggesting further that growth inhibition under these acid conditions was due to Al toxicity.

These trials indicate that the optimum pH for hybrid poplar (DTAC 32) growth under greenhouse culture occurred at a soil pH of approximately 6.5. The poplar cuttings were very sensitive to high Al levels and acid soils. The pH requirements for nursery stock production have to be confirmed by field experiments.

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Table III-1: Fall pH levels of the Ap horizon treated with spring-applied limestone obtained from different suppliers, Kemptville nursery

Year	Compartment	Limestone Supplier	Application Rate (kg/ha)	Soil pH
1979	53	CIL	500	6.2
			1000	6.0
			2000	6.4
			3000	6.2
1980*	84	CIL	0	5.5
			4200	5.5
			8000	5.6
			17200	5.7
1981*	84	Contractor	0	6.0
			4200	7.2
			8000	7.4
			17200	7.9

* Mean pH of 4 replications.

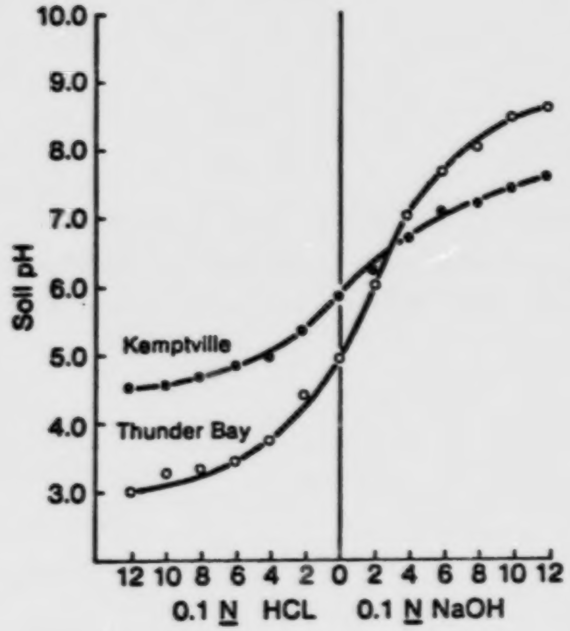


Fig. III-1: Buffer curves of plow layer soils from the Kemptville and Thunder Bay Nurseries (X axis is ml of base or acid added)

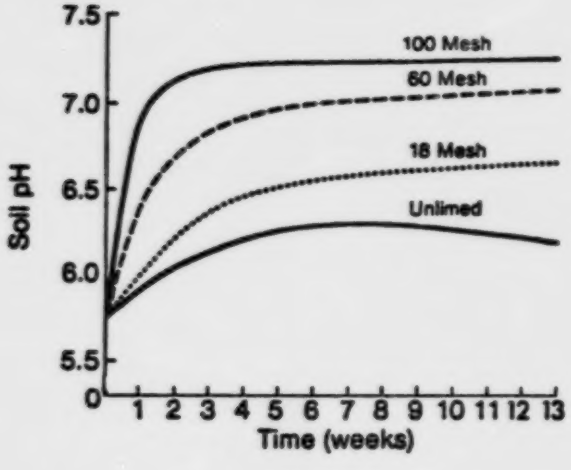


Fig. III-2: Effect of particle size of limestone in raising the pH of Kemptville nursery soil incubated at 30°C (CIL limestone, applied at an equivalent 8000 kg/ha)

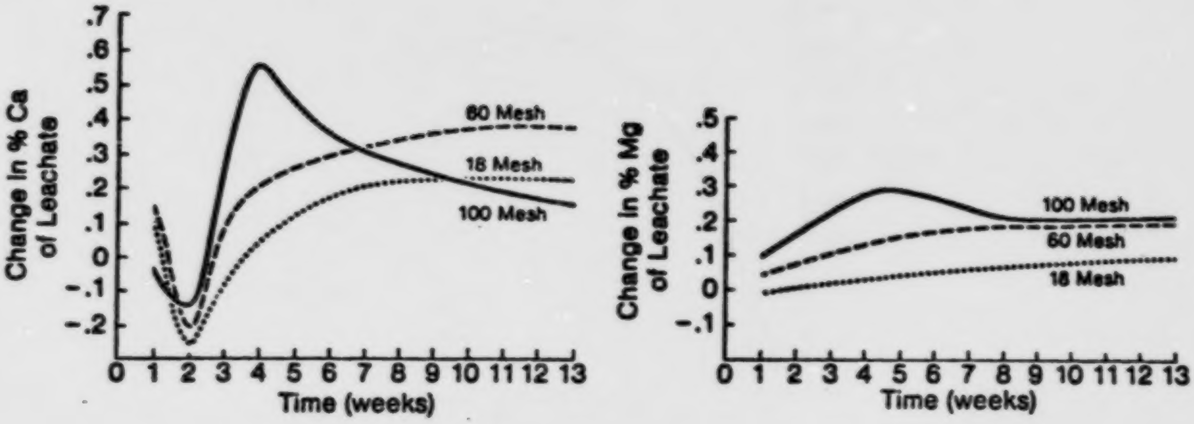


Fig. III-3: Change in the Ca and Mg concentration of leachates collected from incubated nursery soils treated with limestone of variable grain size
(CIL limestone applied at an equivalent 8 t/ha)

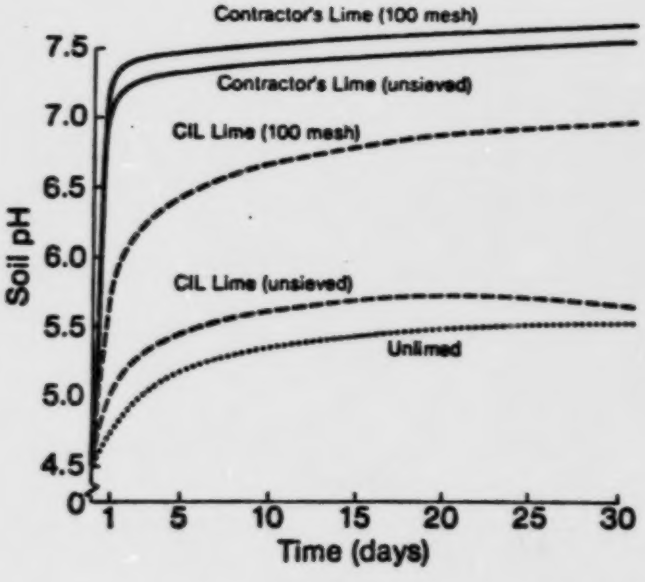


Fig. III-4: Effect of lime source and particle size on the pH of Kemptville nursery soil incubated at 30°C

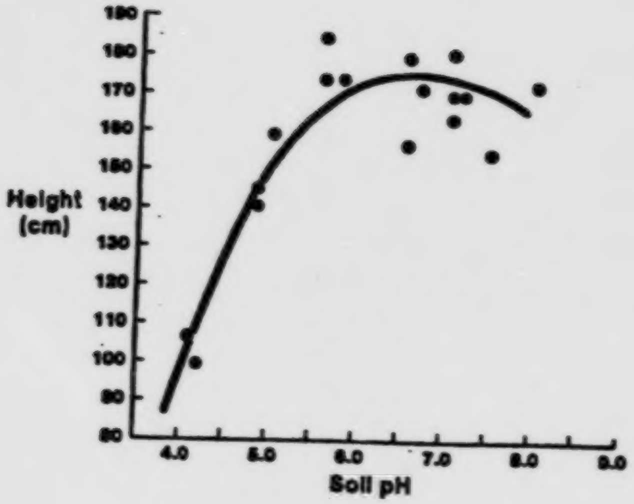


Fig. III-5: Height growth of 20-week-old potted hybrid poplar (DTAC 32) in relation to soil pH

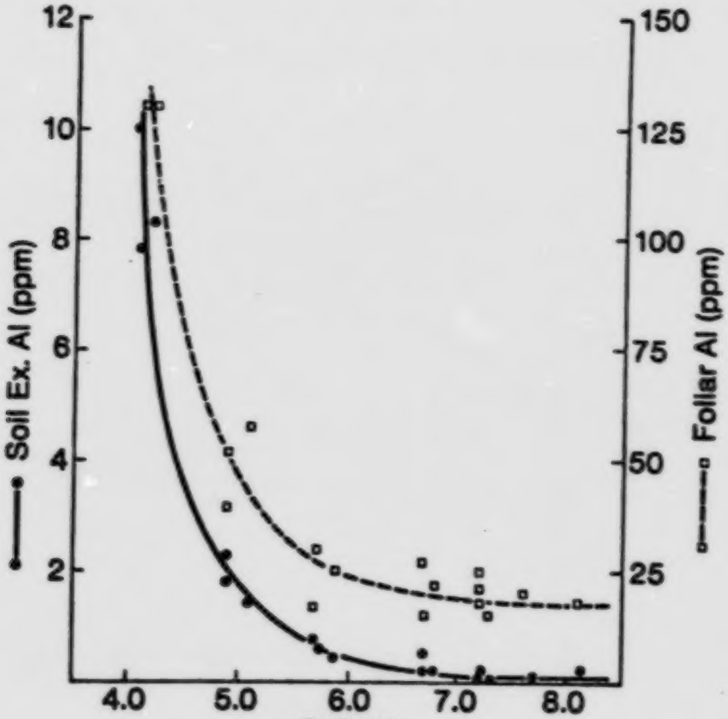


Fig. III-6: Aluminum levels in the soil and in the foliage of clone DTAC 32 as a function of soil pH

IV

APPLYING SOIL AMENDMENTS

Grant Leeder

In order to maintain an organic carbon content in our nursery soils at a level of three per cent, it is necessary to add peat.

In 1978, a project was initiated to excavate peat from a large peat bog at Hallville, only 11 miles from the Kemptville nursery. The bog, which is controlled by the Cornwall District Fish and Wildlife Branch, covers more than 1215 ha of Crown land and is approximately 1.8 m deep.

One of the major problems in the project was to build roads that would support the large tandem trucks and tractor trailers used for hauling the peat. The problem was solved when salesmen from DuPont of Canada suggested using typar -- a granular substance that prevents peat from mixing with gravel but allows water to seep through.

Typar is produced in rolls 5.5 m wide and 180 m long. The rolls are laid out over the bog; approximately 46 to 60 cm of granular material is spread over this and topped with another 15 cm of granular "A" material.

The excavation contract is tendered out on a per-cubic-yard basis. The number of cubic yards is determined by the amount each truck hauls. The bulk peat is then stockpiled in specific amounts. For example, if a compartment requires 1000 cubic yards, that amount will be placed in a pile to be screened and added to the soil the following season.

The peat screening is also tendered on a per-cubic-yard basis. The peat, which has been previously measured and stockpiled, is screened and spread on the compartments with farm-type manure spreaders. The application is made by spreading, discing in, and plowing half of the peat stockpile, and then spreading and discing in the remainder.

The excavation contract also includes the cost of road building for the transport of the peat from the site.

V

HERBICIDES AND APPLICATION EQUIPMENT

Dr. C.G. Waywell

Almost all herbicides that have some potential for use in forest tree nurseries should be considered as experimental compounds. The involved and costly procedures required in order to register herbicides have forced companies to put registration for use in nurseries far down the list of priorities. Because this is a small market area, herbicides which may be used in nursery weed control programs will be among those used in agriculture.

Information required for herbicide registration includes data from feeding tests and other toxicology materials; from field trials that provide information on both the weed species controlled and crop tolerance; and proof that they will not be a threat to the environment. If we can produce accurate, environmentally safe results to assure the chemical companies that herbicide use will not injure nursery trees, then the companies will consider applying to Ottawa to have registrations extended to include forest tree nursery use.

Investigations of "more experimental" compounds should be limited until there is some assurance that they may be accepted for use on a major crop. Perhaps setting up some plots for observation would be sufficient at this stage.

Herbicides

Compounds which have been used by MNR follow:

Gesagard (prometryne), which is one of the triazine group of herbicides, is primarily used as an application preemergent to the weeds. The herbicide is absorbed through the plant's roots and leaf surface. It then passes through the water-conducting tissue (xylem) to the leaves and growing points, where it inhibits photosynthesis. Sublethal quantities can, therefore, reduce the quantity of food material produced by the leaves, which will cause reduced growth of roots and above-ground parts. Postemergent applications have been successful in the control of small weeds. Its primary use is for potato, celery, and carrot crops. It is not as persistent in the soil as simazine, as it is about 14 times as soluble in water at 20°C. Under dry or cold conditions, which reduce both chemical and microbial decomposition, it can remain in some soils longer than three months. It is considered to have a very low degree of toxicity to mammals and fish.

Some chemical company representatives have said that it may be a bit "hot," so be careful with rates of application and calibration of equipment.

Roundup (glyphosate) is an excellent postemergent herbicide that is used in many parts of the world. It affects the growing points of plants (both top and roots) and is particularly effective in control programmes for perennial grasses and broadleaf weeds. It has been reported to control weeds without damage to conifers, but the conifers must be dormant or nearly so. In the Guelph area, there has been injury to both juniper and cedar trees when Roundup was applied before October.

Roundup is absorbed through the leaves and green bark. Because the herbicide is rapidly absorbed by the soil complex, it is ideal for use in site preparation. The main route for breakdown of this compound is through microbial degradation; therefore warm, moist soil conditions are required. All the breakdown products have been studied and the end products are normal constituents of the soil.

Goal (oxyfluorfen) has been used experimentally as both a preemergent and postemergent treatment, at between 0.56 kg/ha and 2.24 kg/ha active. The higher rate is only necessary for the control of larger weeds (18 to 20 cm tall), and should not be used on young nursery trees. A large proportion of the weed species found at the forest tree nurseries is susceptible.

Goal has been registered for nursery use in the United States, but some additional information is needed before it can be considered for registration in Canada. There is a possibility that this herbicide can be used in a mixture with fungicides, but more work is needed. If it were registered for this type of application, it would fit into the spray program of the nursery and reduce costs.

Dual (metolachlor) is an excellent herbicide for the control of annual grasses and nutsedge. It is used as a preplant or preplant-incorporated treatment. It does not control perennial weeds. The main use pattern is in corn, soybeans, white beans, and potatoes. Because it does not control many broadleaf weeds, it should be used with another herbicide in the program.

Devrinol (napropamide) has been used successfully in a wide range of ornamental nursery crops. It is registered elsewhere for use in established fruit and nut orchards, and has been shown to be safe for a number of vegetables. The picture, at present, is not clear about the possibility of registration in Canada.

Ronstar (oxadiazon) is mainly used for weed control in rice. It has been accepted for registration in many countries; notwithstanding, authorities in Ottawa want more data. Apparently, the laboratory that provided some of the original data is no longer in business; so, although the reports are available, the raw data used for the reports are not. Since the raw data are required by Ottawa, the authorities are still negotiating.

Ronstar is both an effective preemergent to weeds and an early postemergent treatment. Therefore, many of the weed species found in nurseries are controlled.

Princep (simazine), a member of the triazine group of herbicides, has been used since the mid-1950s. Initially it was used for corn in Ontario, but its persistence in the soil created problems with the crops that followed, so it was soon replaced by atrazine. Although it has been applied in both forest tree and ornamental nurseries, it may cause problems as it tends to stay in the soil. For years we have recommended that it should not be used where the stock is to be removed and replaced with another planting, or under ornamental shrubs or trees if the area underneath is to be underplanted to bedding plants or groundcover.

The solubility of simazine in water at 20°C is only 3.5 ppm, while the solubility of prometryne under the same conditions is 48 ppm. For this reason, simazine tends to remain in the top few centimetres of the soil profile, except in very coarse-textured soils.

There have been a number of cases of crop injury in ornamental conifer nurseries where higher rates of simazine have been used. In two of these, the nurserymen lost at least a year's growth on large specimen trees.

Glean (DPX4189) is a very effective herbicide, but it appears to be much too persistent in the soil to consider using it in the nursery at this time.

Fusilade (TF1169 or fluazifop-methyl) is an excellent herbicide for grass control. It degrades rapidly and will not leave a residue in the soil. The main problem with this compound is that more data are required before it will be considered for registration and used in conifer nurseries. Other herbicides must be used in the program to control the broadleaf weeds. Rates of application range from 0.12 kg/ha to 0.5 kg/ha active.

Poast (sethoxadin) is another excellent herbicide for grass control that has proven to be safe on a number of crops. Development of this compound is, perhaps, not as far along the route to registration as Fusilade.

Dacthal (chlorthal dimethyl) is probably registered for us on more crops than any other herbicide. Conditions for weed seed germination must be good or control will be poor. It is used only as a preemergent herbicide. Loss from the soil is through microbial and chemical breakdown. I know of no reports of this herbicide being detected in soil the following year.

Enide (diphenamide) is the same herbicide that was sold as Dymid a few years ago by another company. Many nurserymen have used this compound in combination with Dacthal or with low rates of simazine on lined-out stock. It is used for tomatoes, peppers, strawberries, and tobacco, but there have been problems with soil residues for fall-sown cereals as well as other crops sown early in the next season. Loss from the soil profile is mainly through microbial activity. Cool or dry conditions, therefore, favour its retention.

Application Equipment

Most herbicide applications are made with a sprayer using water as the carrier. Many herbicides are soluble in water but wettable powders are common. A short period of agitation is all that is required to ensure a uniform mixture of the soluble herbicides. The wettable powders require mechanical or other forms of agitation to ensure that the particles stay in suspension. Newer flowable formulations have smaller particle size, and tend to stay in suspension with less agitation.

It should not be necessary to use a pressure setting of more than 30 lb/in^2 to 35 lb/in^2 to apply herbicides in the nursery. The orifice tips on the nozzle bodies are designed to produce a fan-shaped spray pattern, with uniform distribution across the width of the boom at this pressure. A higher setting will produce a much larger proportion of very small droplets, which tend to drift away from the target area.

The most common problems I have observed have been caused by faults in application. Aside from obvious errors in calculation or the use of herbicides not recommended for a particular crop, problems can usually be attributed to faulty calibration or poor maintenance of the sprayer. Proper maintenance requires:

a) cleaning the sprayer after completion of a treatment;
b) ensuring that all hose connections, etc., are tight;
c) using 50 mesh screens for all wettable powders;
d) replacing orifice tips as they wear.

Most problems I have observed have been due to failing to do the first or the last of these. Orifice tips do wear, particularly when wettable powders are used, and cannot provide uniform distribution of the herbicide. I have seen sprayers that have been in use for ten seasons, and they still have the original brass orifice tips in the nozzle bodies. Although stainless steel orifice tips are the most expensive, they last more than 70 times as long as brass.

A great deal of work has been directed toward developing better methods of applying herbicides. One method was to use air blast as the substitute for a water carrier. The first machines used were modified orchard sprayers. In one way they worked, because the quantity of water required for spraying was reduced to a few gallons per acre; the problem was that it was not possible to confine the spraying to the particular target area. Later, other machines using air as the carrier were developed, but the same problem caused them to be discarded.

A controlled droplet applicator was developed to enable the grower to use lighter equipment and thus reduce compaction of the soil. Spinning cones were used initially, but there was no control of droplet size. By incorporating small teeth or projections on the rim, the droplets were thrown off from the tip at each projection and the desired droplet size was obtained. This is the principle behind the Herbi and the Micromax applicators. I have used the Herbi over several years in a vineyard in the Niagara Peninsula to apply approximately half a gallon of the spray mixture (water and Roundup) per acre of ground covered, and I obtained excellent control of bindweed without injury to the grapevines. This type of application equipment may have a place on the tree nursery.

A more recent development has been an attempt to put an electrical charge on the particle of liquid in order to create dispersion of the liquid and better coverage of the plant surface. A plant treated with material which fluoresces under ultraviolet light gives a striking demonstration of the effective coverage of both upper and lower leaf surfaces obtained by this method. The Electrodyne is an example of this type of equipment. It can be used to apply special oil formulations of herbicides. At present I have some Fusilade and 2,4-D formulations, which will be applied at some nurseries this season. Formulations of other herbicides are being developed by the companies concerned.

Safety

The safe use of herbicides is mainly a matter of applying common sense. Few herbicides are dangerous; however, one should cultivate procedures which ensure safe conditions.

1. Do not use mixtures of herbicides, or mixtures of herbicides and fungicides or insecticides, unless someone has provided reliable information on the safety of the mixture or mixtures for the crop.

2. Do not use any experimental compounds, unless you are provided with enough information about their toxicity to ensure that there will be no problems when they are used sensibly.

3. Do not wear the same clothing when spraying over a period of several days.

4. Do not use high-pressure settings. They are not necessary when using herbicides in the tree nursery.

5. Do use a mask or filter when handling wettable powders. If practical, use a fume hood.

6. Do wash as soon as possible after accidental exposure, and change your clothing immediately if it is wet with the spray mixture.

7. Do calibrate the sprayer frequently.

VI

PIECEWORK HAND WEEDING

Robert A. Klapprat

Weed eradication remains a very important but costly task on a tree nursery. This operation can be accomplished manually, mechanically, chemically, or, through a recent option, electrocution. It is doubtful that any one of these options can accomplish the task alone, as each has its own limitations in effectiveness or affordability. It is most likely that a combination of all will give the best result.

Attempts have been made to economize on each of the options available. This report outlines our attempt to introduce piecework, and thus increase the efficiency of the manual-weeding operation.

Developing the Pay Schedule

During the regular hand-weeding operations with manual workers on an hourly rate, data was collected to assess their accomplishment. The number of lineal metres weeded, the time required, and a visual assessment of the degree of difficulty was recorded. Although it was not our intention to change the hourly earnings of our employees ($8.83 including vacation allowance), we did anticipate greater efficiencies, so a reduced rate ($4.50) was arbitrarily used in calculation for pay rate determination. In compartments, which from visual observation shared a fairly equal but low degree of difficulty, to weed 16 000 lineal metres took 125 hours ($564, at $4.50 per hour); one lineal metre then took 0.47 minutes and cost 3.5¢. In compartments, which from visual observation presented a higher degree of difficulty, to weed 6000 lineal metres took 238 hours ($1071, at $4.50 per hour); one lineal metre took 2.38 minutes and cost 17.5¢.

These durations (0.47 and 2.38 minutes) and their corresponding pay rate (3.5¢ and 17.5¢) were used as extremes, and the differences between them proportioned to reduce the intervals between them as shown in Table VI-1. To complete the table for most situations, the trend was extrapolated to 4.5 minutes per lineal metre.

Assigning the Pay Rate

In order to implement this pay schedule, one three-metre plot was randomly located in every second flat of the area being considered for weeding. The time required to hand-weed these plots was then recorded (see Table VI-2) with the aid of a stopwatch. These times were then averaged to determine the time to weed one lineal metre, and the pay rate was then assigned from Table VI-1. The area within a compartment which appeared to have the same degree of difficulty was considered to be a unit, and would be assigned a single pay rate. This area could vary in size from a few flats to the entire compartment; however, it was desirable to keep the units as large as possible. Several nursery compartments can be assessed in a couple of days by one person.

Implementing the Plan

After the plots were weeded, pay rates (to apply to this round of weeding only; areas would have to be reassessed for subsequent operations) were assigned as follows:

Compartment 39	12.25¢ per lineal metre
Compartment 33	8.75¢ per lineal metre
Compartment 13	7.0 ¢ per lineal metre
Compartment 7	3.5 ¢ per lineal metre
Compartments 24 and 14	3.5 ¢ per lineal metre
Compartment 6	7.0 ¢ per lineal metre

A crew of eight were assembled for this project, under the supervision of a crew boss who was responsible for recording accomplishments (Table VI-3). (The crew boss, who is paid an hourly rate, is also responsible for plot weeding and assigning the pay rate.) The eight individuals were assigned the first eight flats of the compartment, and were expected to weed the flat, which consisted of six or eight rows of trees, as well as an adjacent path. The first person to complete a flat was then assigned the ninth flat, the second person the tenth, and so on. Very difficult flats were occasionally encountered, but it became apparent that over the duration of the operation each crew member would encounter such an exceptional patch.

The following summarizes the total earnings of each crew member, the average amount each earned in one hour, and the average for the crew on each of the two hand-weeding operations.

	Piecework Project 1		Piecework Project 2	
Employee	Total Cost*	Average Hourly Rate	Total Cost	Average Hourly Rate
No. 1	$298.48	9.32	$281.50	11.72
No. 2	233.64	9.73	414.50	12.79
No. 3	289.89	7.77	246.15	7.69
No. 4	203.45	6.35	269.33	8.41
No. 5	245.07	7.65	265.14	8.28
No. 6	191.89	7.99	327.27	10.22
No. 7	274.71	8.58	289.58	9.04
No. 8	253.90	7.93		
Overall		8.16		9.75

* Not all crew members worked the same number of hours.

Conclusion

Piecework Projects 1 and 2 were completed during October of 1982, and comparisons show that there was an 80 to 100 per cent increase in efficiency over conventional hourly salaried weeding crews. Further comparisons were made with two contractors, A.R.C. Industries, a non-profit organization working under subsidy and limited in versatility, and Green Things, a shrewd but conscientious profit-oriented commercial contractor.

	Average Cost		
	Per Lineal Metre	Per Acre	Per Hectare
Piecework	6.1¢	$136.58	$ 334.00
Contractor			
Green Things	24.0¢	$535.00	$1131.00
A.R.C.	5.4¢	$120.00	$ 296.50
Hourly salaried crew (est.)	11.6¢	$258.00	$ 634.00

The described projects were carried out during the pleasant days of September and October, when weather conditions were ideal for physical activity, insect pests were non-existent, and soil moisture conditions allowed for easy extraction of weeds. The main season for weed control is during the hot summer months, when it is expected that worker efficiency will be significantly reduced because of high temperatures, insect pests, and weed extraction difficulties. This will affect the earnings of individual crew members, but will only slightly alter the weeding costs to the nursery.

Table VI-1: Developing the pay schedule

Time Required to Weed One Lineal Metre	Pay Rate Per Lineal Metre
Less than 0.5 minutes	5.5 ¢
0.5-0.75 minutes	7.25¢
0.75-1.0 minutes	9.0 ¢
1.0-1.25 minutes	10.75¢
1.25-1.5 minutes	12.5 ¢
1.5-1.75 minutes	14.25¢
1.75-2.0 minutes	16.0 ¢
2.0-2.25 minutes	17.75¢
2.25-2.5 minutes	19.5 ¢
2.5-3.0 minutes	23.0 ¢
3.0-3.5 minutes	26.5 ¢
3.5-4.0 minutes	30.0 ¢
4.0-4.5 minutes	33.5 ¢
More than 4.5 minutes	37.0 ¢

Table VI-2: Plot weeding for pay rate determination
Example

Compartment No. 19 & 20 East Side   Date: October 6, 1982

PLOT #	TIME	PLOT #	TIME	PLOT #	TIME
1	2.35	24	1.22		
2	0.53	25	1.00		
3	1.28	26	1.16		
4	1.03	27	0.42		
5	0.43	28	2.15		
6	1.16	29	1.30		
7	1.36	30	1.19		
8	0.55	31	1.22		
9	0.59	32	0.31		
10	1.40	33	1.25		
11	2.36	34	2.26		
12	2.16	35	4.23		
13	0.50	36	2.47		
14	1.16	37	2.23		
15	1.03	38	3.10		
16	1.29	39	3.31		
17	2.28	40	2.32		
18	1.47	TOTAL	76.38	(76 minutes,38 seconds)	
19	1.11				
20	1.30				
21	1.01				
22	1.27				
23	1.22				

40 (plots) x 3 (each plot is 3 lineal metres) = 120 lineal metres
It takes 77 minutes to weed 120 lineal metres
Therefore, to weed 1 lineal metre (77/120 = 0.64) it takes 0.64 minutes
Therefore, the pay rate per lineal metre is 7.25¢ per minute (see Table VI-1)
To weed 79 flats (there are 79 flats in this compartment), each at 134 lineal metres long (79 x 134 = 10 586 lineal metres), will cost (10 586 x 7.25¢) $767.50

Table VI-3: Piecework Weeding Example

Crew Member: John Doe

DATE	COMPT. #	FLAT #	FLAT LENGTH	PAY RATE ¢	LOCAL CODE	HOURS PER COMPT.
(East)						
Oct. 12	3	1	119	7	6711-4265-20	
Oct. 12	3	8	119	7	6711-4265-20	
Oct. 12	3	15	119	7	6711-4265-20	
		TOTAL	357			3 1/2
(West)						
Oct. 12	4	4	115	5 1/4	6711-4265-10	
Oct. 12	4	11	115	5 1/4	6711-4265-10	
		TOTAL	230			1
(East)						
Oct. 12	4	1	114	7	6711-4265-20	
Oct. 12	4	8	114	7	6711-4265-20	
Oct. 12	4	10	114	7	6711-4265-20	
		TOTAL	342			2 1/2
(West)						
Oct. 12	5	1	118	3.5	6711-4265-40	
Oct. 12	5	8	118	3.5	6711-4265-40	
Oct. 12	5	10	118	3.5	6711-4265-40	
Oct. 12	5	14	118	3.5	6711-4265-40	
Oct. 12	5	18	118	3.5	6711-4265-40	
Oct. 12	5	26	118	3.5	6711-4265-40	
		TOTAL	708			1
						8 Hours

Total cost

(357 + 342) 699 lineal metres x 7.0 ¢ = $ 48.93

230 lineal metres x 5.25¢ = 12.08

708 lineal metres x 3.5 ¢ = 24.78

TOTAL $ 85.79

Joe Kemptville

Signature of Crew Boss

John Doe

Signature of Crew Member

VII

NURSERY COST ACCOUNTING SITUATION, 1983-84

A. Wynia

In a way, it is unfortunate that the present system of expenditure accounting in Ontario nurseries started long ago, before the days of P.P.B., M.B.A., and M.I.S., with the name "Nursery Cost Accounting System." The name seems to have connotations attached, such as thick ledger books, daily entry routines, and elaborate calculations producing irrelevant figures. As a result, it has always been first on the "hit list" in reviews by administrators, whether they were foresters or accountants.

The fact is that the present expenditure accounting system can, and does, provide for a detailed work planning framework, operational cost studies, internursery comparisons, plus a reasonable estimate of the cost levels of the different age-class products of each nursery. Thus, it provides the basic financial information framework needed to make informed managerial decisions at the nursery.

A recent, quick survey among the seven major nurseries revealed that almost all are using all or part of the present set of instructions in running their business, with some exceptions where sufficient details were not covered. The only aspect that is disturbing is that several nurseries are being told, by their Regional accountants or Regional forester, how many project codes they may use. I have difficulty accepting this as a Regional responsibility, and such practices will eliminate any kind of progress we could make on a provincial scale.

Late this winter I started work on writing a new manual for a nursery M.I.S., which consolidates our present systems and prepares us for computerization of the analysis. Although I made some progress, the job has not been completed. In any case, several changes needed to be made halfway through as a result of the new series of subactivity codes which are part of the 1984-85 work plan. I still expect to have the manual ready before January 1, 1984.

There are a few problems now with the framework of the occupation report, the forecasting, and coding. My main concern at this time is to devise an equitable procedure to allocate the overheads on the various nurseries, now that the container programs are rapidly overtaking the bare-root stock production in financial significance at certain root centres.

One of the items most needed, now that several of our products have their own subactivity code, is a subactivity for overhead to be used as subactivity 4331 is being used in the MNR Districts and Regions. As the coding manual for 1984-85 now reads, all items of overhead such as headquarter maintenance and office salaries will likely be budgeted under STR production while, for example, a substantial workload OLA production might get off free of overhead. In the actual cost calculations there is a procedure to assess an adequate overhead charge, but this is after the fact in the case of constraint exercises on OLA.

This is the appropriate point to suggest that those responsible for maintaining the nursery records make an attempt to get a good set of figures on the recent spring ship, making the adjustments for previous fall lifts and destruction of surplus stock and transfers of stock in or out.

My two main concerns at this time, then, are these:

1. Once we get a provincial methodology for nursery M.I.S., it should not be vulnerable to Regional interference with the basic framework.
2. A "nursery administration" subactivity would streamline the managerial process.

VIII

SEEDLING GROWTH PREDICTION AND GROWTH CONTROL

W.R. Bunting

Predicting Growth

One of the more frustrating aspects of nursery work, which I have had to face over the years, has been my inability to grow seedlings of a uniform size from one season to the next. Despite our best efforts — irrigation control and uniformity of cultural treatments — wide fluctuations in seedling size occur when one year's production is compared to another (Fig. VIII-1).

While some of this variation is no doubt due to nursery compartment differences, surviving seedling density differences, annual growing degree day differences, etc., etc., it has long been felt that if we only had a method of predicting these fluctuations, then we might be able to do something to counteract, for example, a larger than wanted seedling at shipping age.

In 1971 at Orono, we set out to establish growth curves for each of our major species. The aim was to develop a stylized curve, based on dry weight, along which we wanted our seedlings to develop. Once the curve was established, in subsequent years samples would be obtained throughout the growing season and the results of these samples compared to the curve to determine how the seedlings were developing (Figure VIII-2). If growth was not developing as planned, we would do something to get it back on track.

The results of this first try were very unsatisfactory. The samples varied greatly in dry weight from week to week. While a power curve gave an excellent fit to these data, no single sample could be used as an indicator of how the seedlings were developing, since the next week's sample might be considerably larger or smaller.

This was obviously a sampling problem. However, since weekly sampling of the seedbeds (even at this unsatisfactory level of accuracy) destroyed large numbers of seedlings, it was decided to develop a growth curve based on diameter, a parameter which could be obtained by non-destructive sampling. We had still hoped to develop a stylized curve and then compare current samples to it to see whether our seedlings were developing as planned.

The form of this growth curve, from early May to mid-September, turned out to be a straight line. After approximately September 15, growth ceased and diameter measurements remained relatively constant until the last observations were made just before freeze-up in mid-November (Fig. VIII-3). This was a surprising result to me, because from a dry weight standpoint a seedling is only half as heavy in September as it will be in November (K.A. Armson, 1960). However, over the years this pattern has repeated itself and the same curve form has been observed in measurements taken at St. Williams, Midhurst, Swastika, and Dryden.

As we obtained additional curves in subsequent years it became obvious that there were differences between these curves (Figure VIII-4). An analysis of covariance showed that while there were significant differences in vertical displacement of the curves, there were few, if any, significant differences in their slopes. Based on this information, we decided to use the slope of the average curve for prediction purposes, and the current measured diameter for the "a" value in the general formula $Y = a + bX$, where Y is the estimate of the September 15 diameter, "a" is the current diameter (just measured), "b" is the slope of the average curve, and X is the number of days left until growth ceases on the 15th of September. This calculation allowed us to estimate, for each sample date, what the September 15 diameter would be, and hence whether our seedlings would be too large or too small (Fig. VIII-5). On most of our curves this led to our prediction (on each of the sample dates) being within $\pm 10\%$ of the seedling's final diameter. For example:

Assume - growing season of 154 days (Apr. 15 to Sept. 15)
- sample date May 15
- measured diameter 1.0 mm
- slope 0.0236 mm/day

Y = a + bX
a = current diameter = 1.0 mm
b = slope = 0.0236
X = days left to September 15
May 15 is 31 days into the season
No. days left = 154 - 31 = 123
Y = estimated diameter September 15
Y = 1.0 + (0.0236 x 123) = 3.90

In compartments where we sampled stock as 1+0, 2+0, and finally 3+0, it was observed that the 1+0 or 2+0 diameter we measured in November would be approximately equal to the diameter measured about May 15 the following spring (Fig. VIII-6). We decided to use this observation to predict seedling diameters a year ahead of time.

Taking the diameter obtained in November, and assuming it will be approximately equal to that observed the following May 15, and using the average slope determined for age-class and species, we calculate what the diameter will be the following September 15 (Fig. VIII-7).

As can be seen here, we were predicting the path along which we expected the seedlings to develop and then we were plotting the measured diameters to monitor this development. As stated in our original aim, if diameter growth was not developing as planned, then some action would be taken to correct it.

We now have four years' experience in this prediction exercise, and of 17 predictions that have been made over this period, only two have exceeded the ±10% acceptable error level that we set (Table VIII-7).

For the 2+0 white spruce, which did exceed the ±10% error level in 1981, the observed growth curve did follow the predicted curve relatively closely until day 124 (about the end of August), when diameter growth ceased (Fig. VIII-8). We are unable to explain this early cessation of growth, for had the seedlings continued to grow at their established rates, the final diameters would have been very close to the predicted diameters by September 15 (day 154).

During the years that these predictions were made, we noticed that from time to time, and for some of the units being measured, the observed diameters early in the growing season varied considerably when compared to the calculated curve (Fig. VIII-9). In this example, the 3+0 red pine diameters were considerably larger than predicted in mid-May (day 38) and continued this way until mid-August (day 120) when they got back on the curve and grew as expected, finishing within -4% of the estimated diameter.

Had we used the prediction function in mid-May to estimate the final diameter of the stock, we would have estimated a seedling much larger than we wanted, and had we taken action to reduce the size of this seedling, we would have ended up with a seedling considerably smaller than desired.

These observations are the same as those made at the Thunder Bay nursery, that any single or small number of current-year diameter observations may not represent how the seedlings are developing and therefore should not be used in any assessment where action is going to be taken to adjust the growth curve.

For this reason we have changed the aim of our growth prediction function. Instead of estimating the curve along which we expect the seedlings to develop and then comparing the observed diameters to see how we are doing, we now accept the predicted diameter (which we calculate in the fall) as being right and base any action to control growth on this estimate. If our past record is to be believed (Table VIII-1), this allows us to obtain estimates of seedling diameters a year ahead that will be within ±10% of the actual diameter, with one chance in ten of being wrong.

Our aim now is to develop stylized growth curves for all our species. These curves are to be based on the size we would like the seedlings to be at the end of each season, and the daily rate (slope) at which we would like them to grow during the following season (Figure VIII-10). At the end of the 1+0 year we will estimate how large our 2+0 seedlings are going to be, and if this size does not meet our 2+0 objectives we will do something to get it back on track. Similarly, we will use the 2+0 diameter to estimate the final 3+0 diameter, and will have an opportunity to fine-tune our growth prescription to reach our objectives.

This should allow us to write a management prescription at the end of the first season that will produce a ship seedling to the desired size year after year. We will take sample diameters at the end of the season, to see how we did, but none during the season, to see how we are doing, because these are unreliable. Additional measurements to adjust the growth curve will not be necessary unless basic changes are made to the fertility level of the nursery compartments.

Controlling Growth

I feel that the aim of any nursery soil management program should be to get the soil to what I like to call "optimum growing conditions" as quickly as possible, and then to maintain it at this level. At Orono these conditions are: organic carbon 3%; pH in the range of 5.0 to 6.0; phosphorus 30 mg/100 g; potassium 0.30 meq/100 g; magnesium 0.50 meq/100 g. Once the soil has reached these levels the only way to manipulate growth through soil fertility is to vary the nitrogen top-dressing applications. (It should be noted here, however, that if nursery soil falls below these optimum conditions lower levels of any of these nutrients may become limiting, and varying amounts of them may have to be applied along with the nitrogen top-dressings to have an influence on seedling growth.)

Normally a seedling growth response curve to fertilizer initially shows a sharp growth increase whose size is directly related to the amount of extra fertilizer applied. In time this growth response starts to decline, then ceases, and finally decreases as increasing levels of fertilizer are applied (Fig. VIII-11). This theoretical growth response curve is usually divided into four sections.

A. Visual deficiencies — nutrient levels in the plant are low enough here that the plants show the typical nutrient-deficient colours.

B. Hidden hunger — in this zone nutrient deficiencies are not noticeable, but increasing levels of fertilizer yield good growth response.

C. Luxury consumption — here increasing levels of fertilizer give very little, if any, increase in growth.

D. Toxicity — further increases in fertilizer cause decrease in growth or even mortality.

If we are to control growth (alter the slope of the growth curve) then I think it is obvious that we should do it within section B, the hidden hunger section of the curve.

Our soil fertility levels at Orono are at, or close to, the optimum conditions just described. We have now had three years' experience in trying to manipulate the slope of growth curves. Our first trial, beginning in 1980, superimposed a replicated trial 0, 0.25, 0.50, normal, and twice normal our regular nitrogen top-dressing application (0N, 0.25N, 0.5N, N, 2N) (Figure VIII-12). The results of this trial on our 2+0 white pine was surprising. The diameter growth curve started out almost from a point source in June, and while the different fertilizer regimes appear to have somewhat sorted themselves out in September, these differences were not significant. This was a real surprise to us, as we have never before done a fertilizer trial where we had not obtained at least some significant differences in growth response.

We repeated this trial on the same stock in 1981 (Fig. VIII-13). Nitrogen applications did significantly affect the slopes of the growth curves. Over the season, the 0N treatment put on only 0.43 mm (4.43-4.0) of growth, while the 2N treatment was capable of putting on 1.8 mm (5.8-4.0), a better than fourfold increase. In this example, applying varying levels of fertilizer for one year was not enough time to affect growth: it took two years for the applications to have significant effects.

Because of the negative results obtained in the first year of our 1980 trial, we began a second series of trials in 1982, as well as carrying on the second-year treatments of the 1980 tests. After consultation with Dr. Timmer of the University of Toronto, it was decided that this second set of trials would have levels of nitrogen from control — zero nitrogen — to twice the normal nitrogen, as before; but that these levels would be applied with and without phosphorus and potassium. The idea was to see if P or K would be limiting at the higher levels of nitrogen we would apply.

In this trial with white spruce, neither phosphorus nor potassium proved to be limiting (Table VIII-2). However, there were significant differences in all other growth parameters measured for the increasing nitrogen levels, except the top/root ratios.

Figure VIII-14 graphically displays the first- and second-year growth curves for this trial. Here, for clarity only, the 0N+PK (control) and 2N+PK treatments are shown. Unlike the white pine trial previously described, this white spruce trial did sort itself out by fertility treatment in the first year, as well as in the second.

In the 2+0 year (the first year of the treatment), seedling diameter varied from 1.95 mm (small) for the 0N+PK application to 2.52 mm (medium) for the 2N+PK application. In the 3+0 year these diameters were, respectively, 3.63 mm (below small) and 5.30 mm (above large).

Since we were able to grow seedlings that were smaller than small and larger than very large by applying from zero nitrogen to twice our normal nitrogen over a two-year period, in theory we should then be able to grow a seedling of whatever size we wanted within the present size-class classification system.

Figure VIII-15 illustrates the average daily growth rate (mm/day) which was achieved during the 2+0 year under the N and N+PK fertilizer regimes. Figure VIII-16 shows the average daily growth rate achieved in the 3+0 season for these two fertility regimes (N and N+PK).

It is interesting to note here that in the 2+0 year (Figure VIII-15) there was no increase in daily growth for increases in nitrogen beyond the "normal" application (142 kg/ha). It would appear, then, that at this rate the seedlings had reached the end of the hidden hunger section of the growth curve and that additional nitrogen put them into the luxury consumption area. In the 3+0 year (Fig. VIII-16) daily growth increased with each addition of nitrogen, right up to the 2N application (390 kg/ha). It appears that we did not reach the top of the hidden hunger section of the growth curve in this series of applications.

With the daily growth data (slope of growth curve) gathered from the first- and second-year results of this trial, it is now a simple matter to calculate the amount of elemental nitrogen required to produce a desired growth curve slope. Table VIII-3 illustrates this point.

These data (Fig. VIII-14) show that over a two-year period, by applying various rates of nitrogen fertilizer, we were able to grow 3+0 seedlings of white spruce from too small to too large. The colour of this stock indicated that the 0N, 0N+PK, and possible the 0.5N, 0.5N+PK, were being produced in the visual deficiency section of our hypothetical growth curve (Fig. VIII-11).

Since we do not, or should not, want to ship seedlings showing nutrient deficiencies, it follows that we should never get ourselves into a position where we would have a 2+0 seedling so large that we would have to cut off all nitrogen in the 3+0 year to reduce the growth curve slope to a desired level. Rather, we should always try to work within the hidden hunger section of the curve and most likely keep the seedlings on the small side over the 1+0 and 2+0 years so that when adjustments are made in the 3+0 season they will be made in the hidden hunger section of the growth curve.

In 1982 we began a repeat of this trial without the PK additions, using the same nitrogen fertilizer rates but beginning in the 1+0 year. No colour differences could be seen in any of the treatment rates at the end of the first season. No significant differences occurred in any of the parameters measured in red pine. In white pine and white spruce significant differences did occur. For these two species, any increase in nitrogen beyond the control treatment resulted in a significant increase in diameter (Table VIII-4).

I feel that the control of seedling growth curves might work this way at Orono:

1. Apply no nitrogen top-dressings during the first growing season.
2. Once the 1+0 November diameters have been obtained, calculate a growth prescription to yield a medium seedling at the end of the second season.
3. After the 2+0 November diameters have been obtained, calculate a final growth prescription to produce the size of seedlings you are aiming for at 3+0 ship.

The success of this procedure depends on no growth factors being limiting. Soil fertility should be at, or close to, optimum conditions, or else the limiting factors should be eliminated by adding extra amounts of these elements in the form of top-dressings. Soil moisture should be monitored and maintained at adequate levels so that seedlings will be able to obtain all the nutrients they require for growth.

In writing a management prescription for growth, one does not have to be limited to fertilizer top-dressings as the sole means of changing the slope of the growth curve. Two other methods come immediately to mind: root pruning and/or wrenching, and soil moisture control.

Table VIII-5 illustrates the effect on 2+0 and 3+0 red pine of various treatments of root pruning and wrenching, beginning in July of the 2+0 year. At the end of the 2+0 year height had not been affected and diameter had been affected only slightly, but the RAI had been increased by 58% when the operational prune was compared with the shallow prune plus wrenching every three weeks.

At the end of the 3+0 year the stock from the shallow prune plus wrenching every three weeks treatment had its height reduced by 22%, its top/root ratio by 46%, its dry weight by 26%, and its RAI increased by 63% when compared with the operationally pruned seedlings.

Soil moisture control may also be used to control growth. Once the troxler moisture density meter has been properly calibrated to the compartment, we may confidently withhold irrigation applications until soil moisture becomes limiting to growth.

One danger in attempting to use soil moisture to control growth is — "What do you do in the wet summer when, for all intents and purposes, the soil does not dry down sufficiently to affect growth?"

Any of these methods may be singularly used to control growth, as was done in the experimental work using nitrogen fertilizer top-dressings; or they may be used in combination to produce the desired results. I feel the latter choice will prove to be the best approach in the long run.

References

Armson, K.A. 1960. The periodic uptake of nutrients by white spruce seedlings in the nursery. In: Lands and Forests Technical Bulletin T. 17-7. 3p.

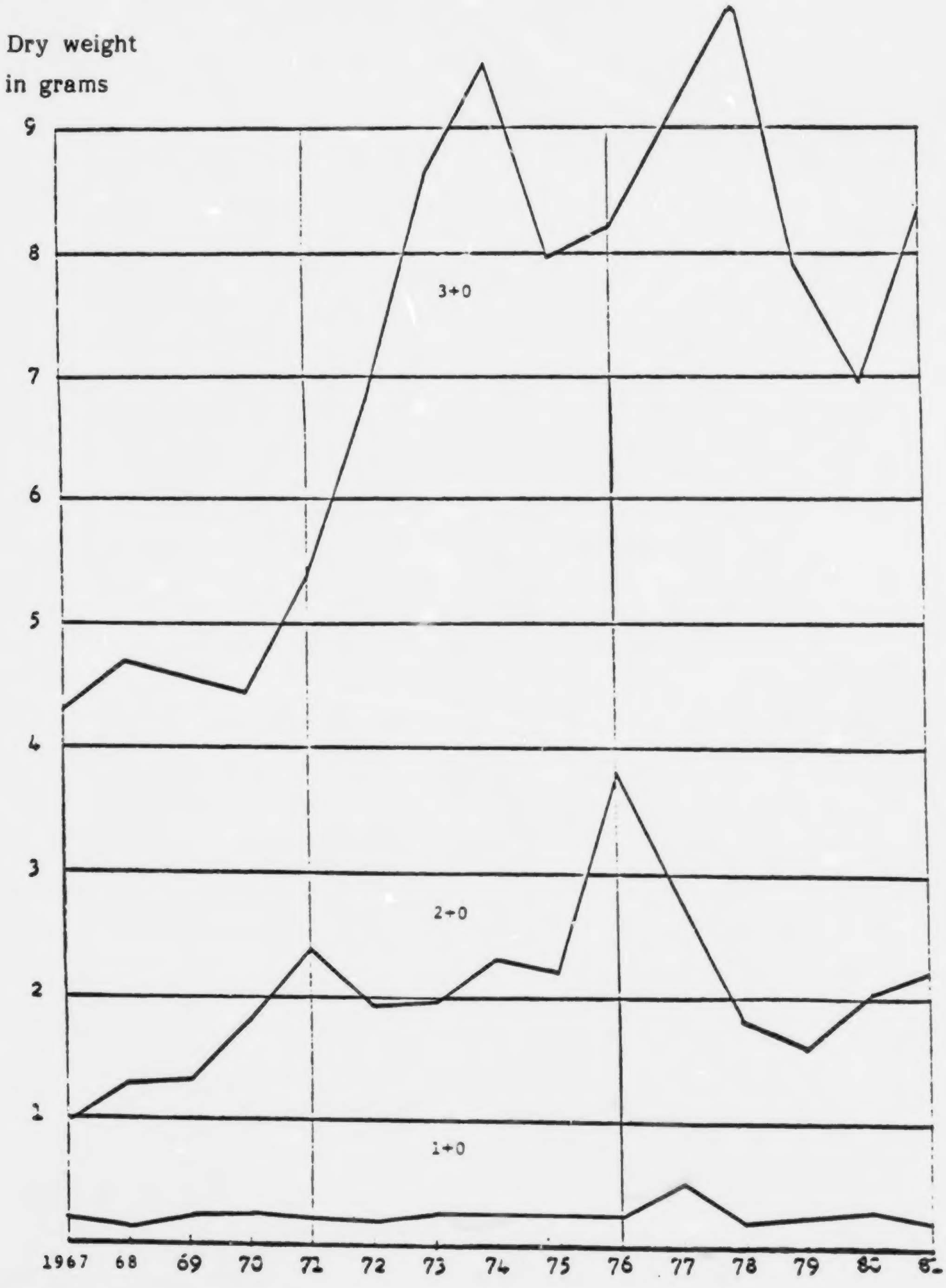


Fig. VIII-1: Fluctuations in seedling size
for white pine over a 15-year period

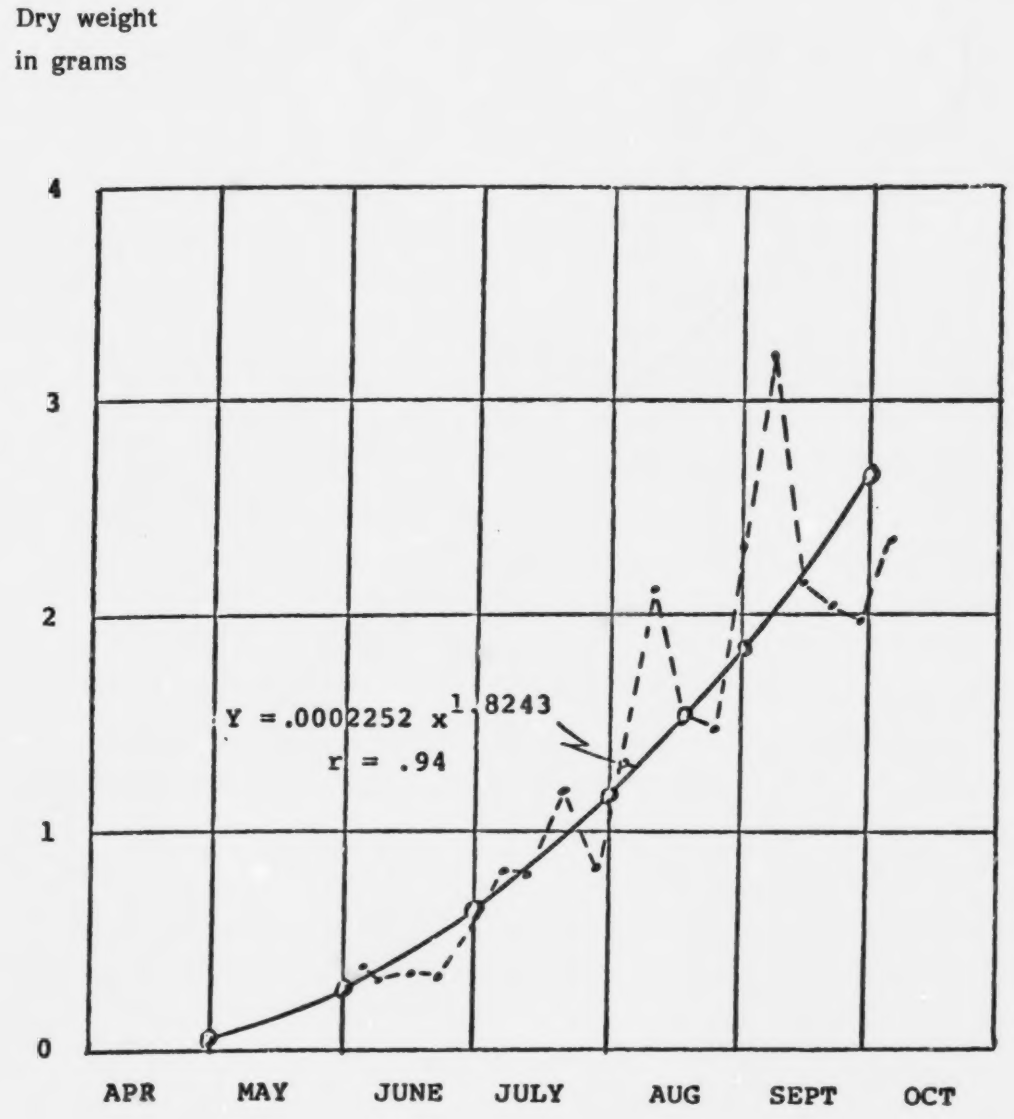


Fig. VIII-2: White spruce (2+0) growth curve in 1971
compared to stylized curve
(each point sample equals four random samples of 20 trees)

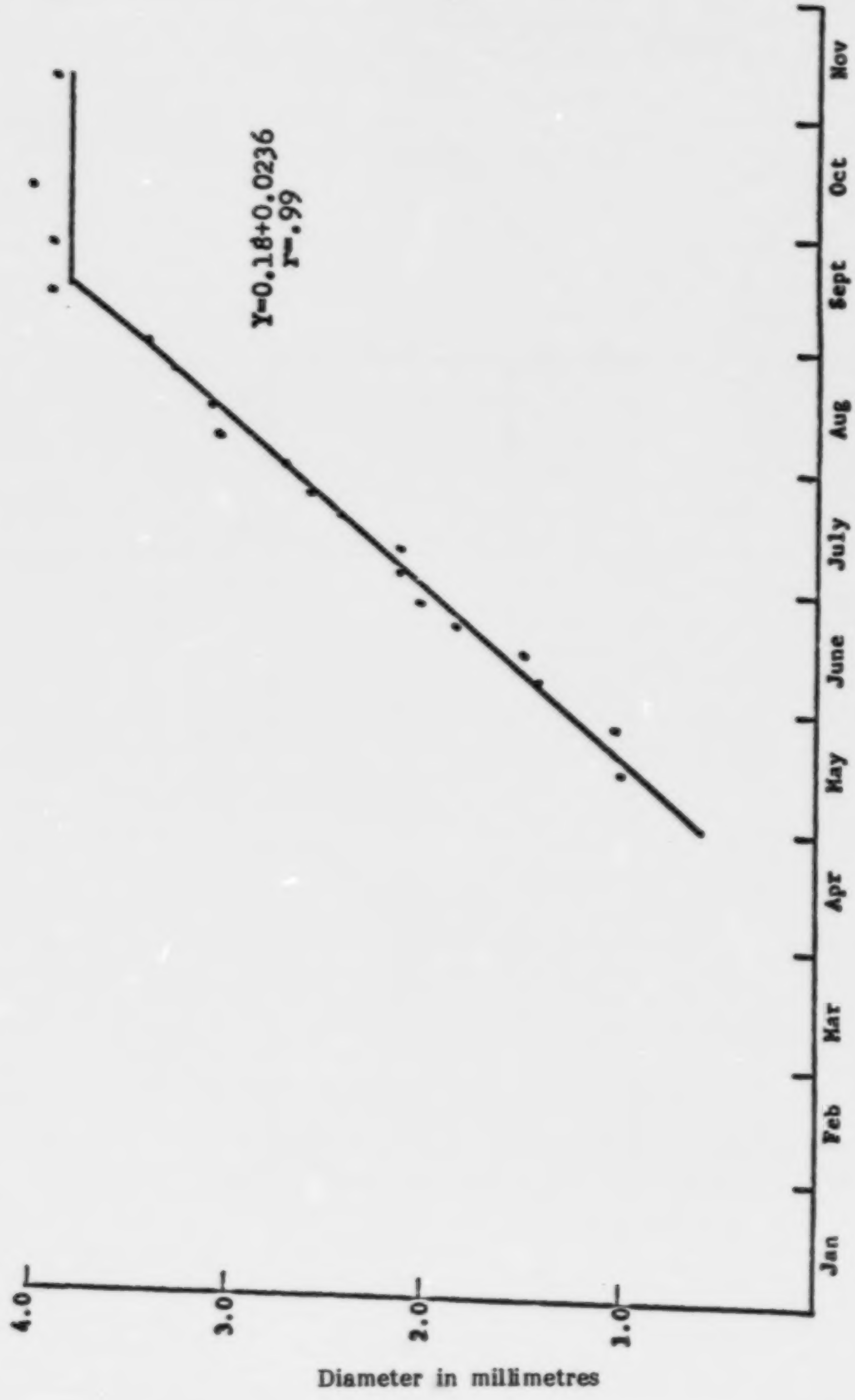


Fig. VIII-3: White spruce (2+0) growth curve in 1978 (H-18)

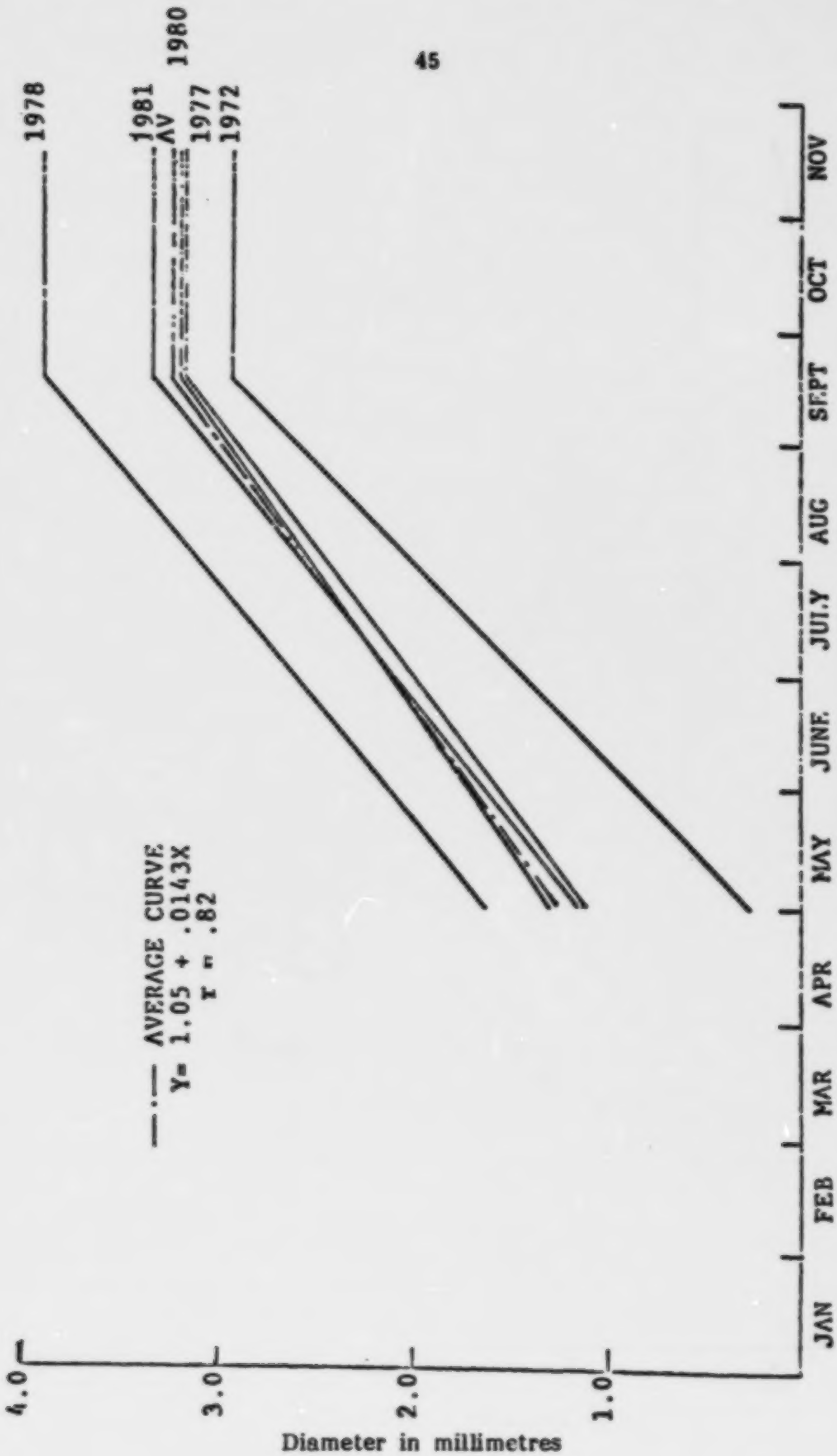


Fig. VIII-4: Red pine (2+0) growth curves and average for five growing seasons

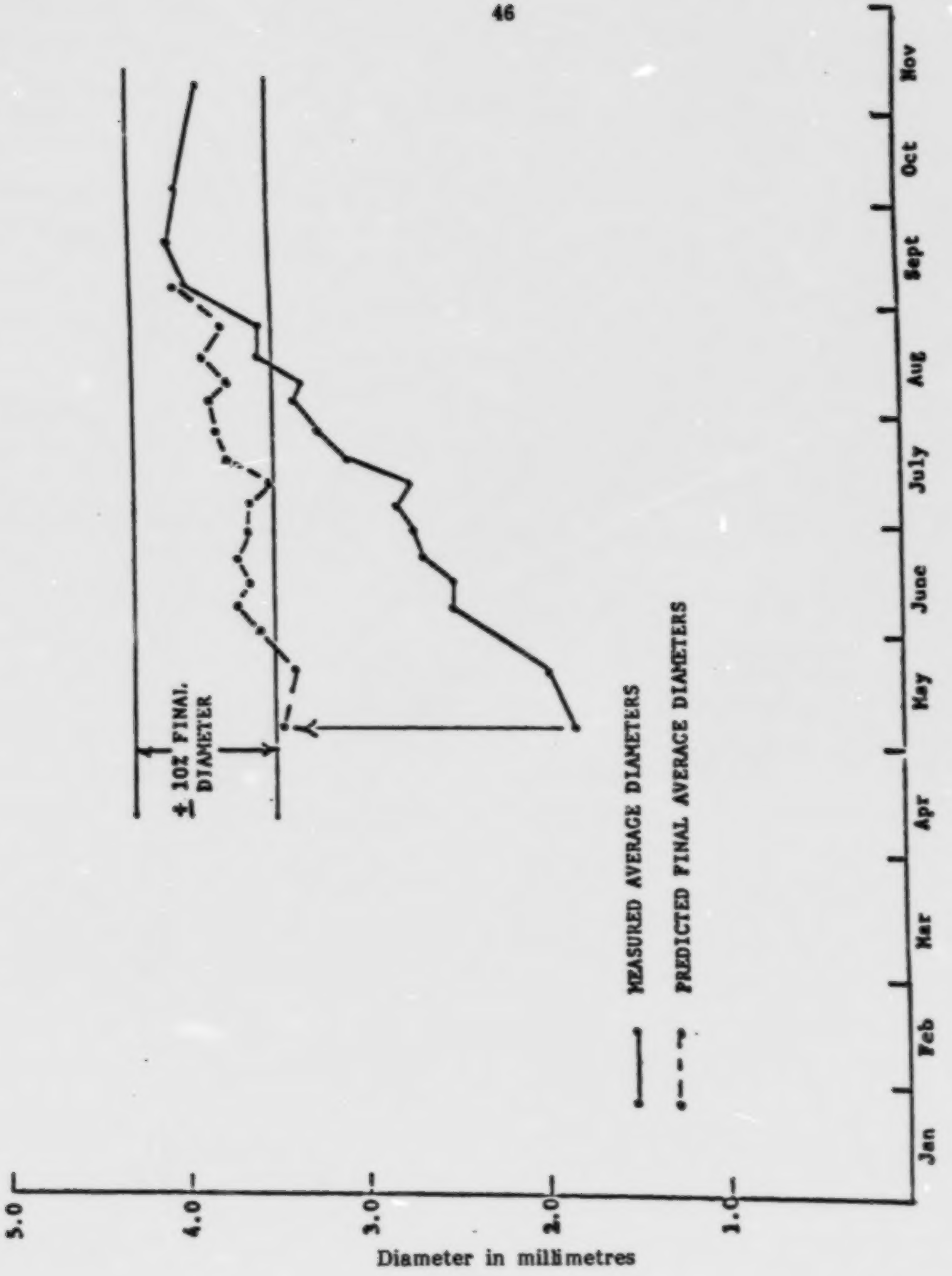


Fig. VIII-5: Red pine (2+0) comparison of predicted and measured average diameters in 1978

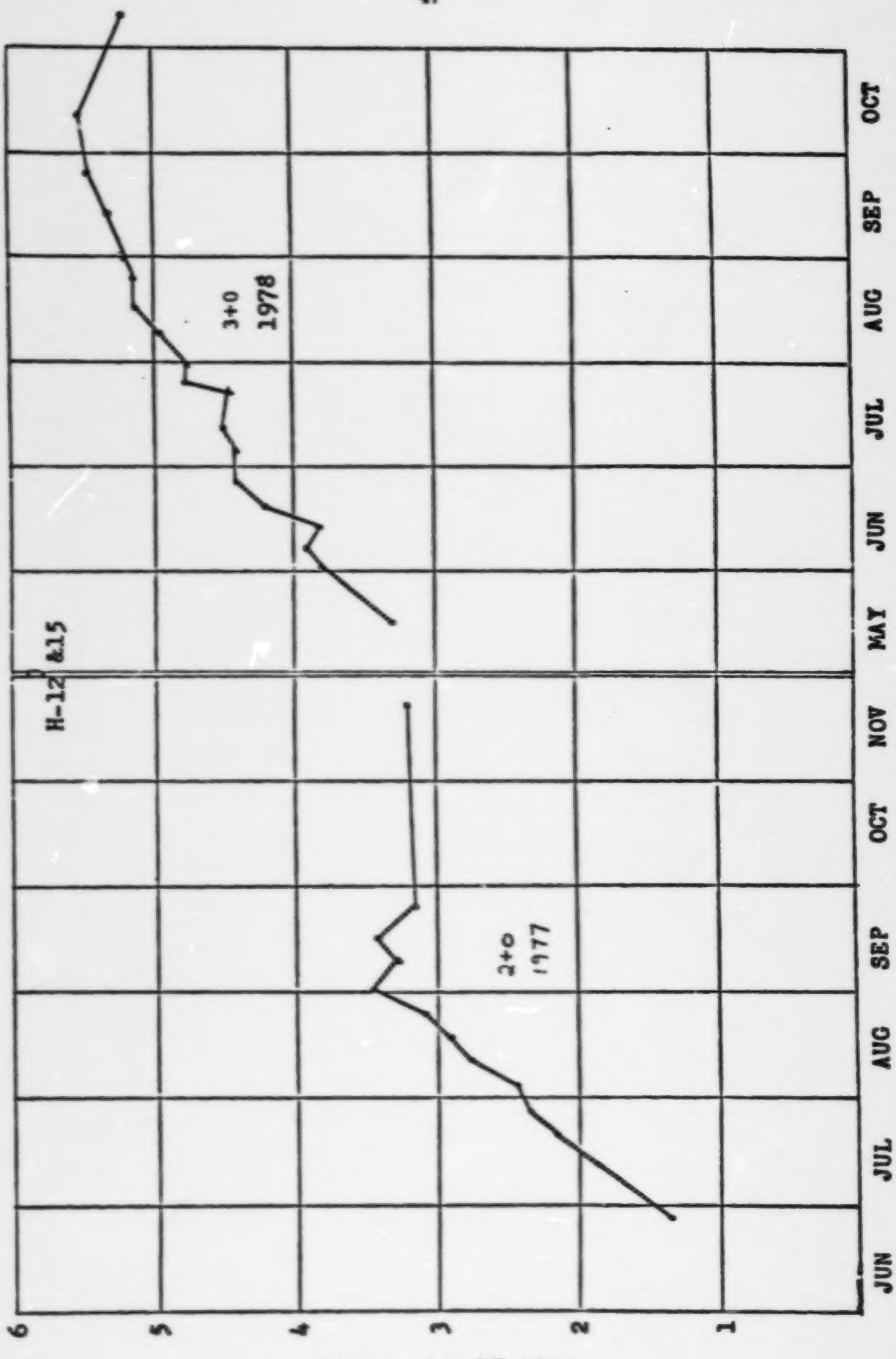


Fig. VIII-6: White pine (2+0) diameter measured on November 15, 1977 and May 15, 1978

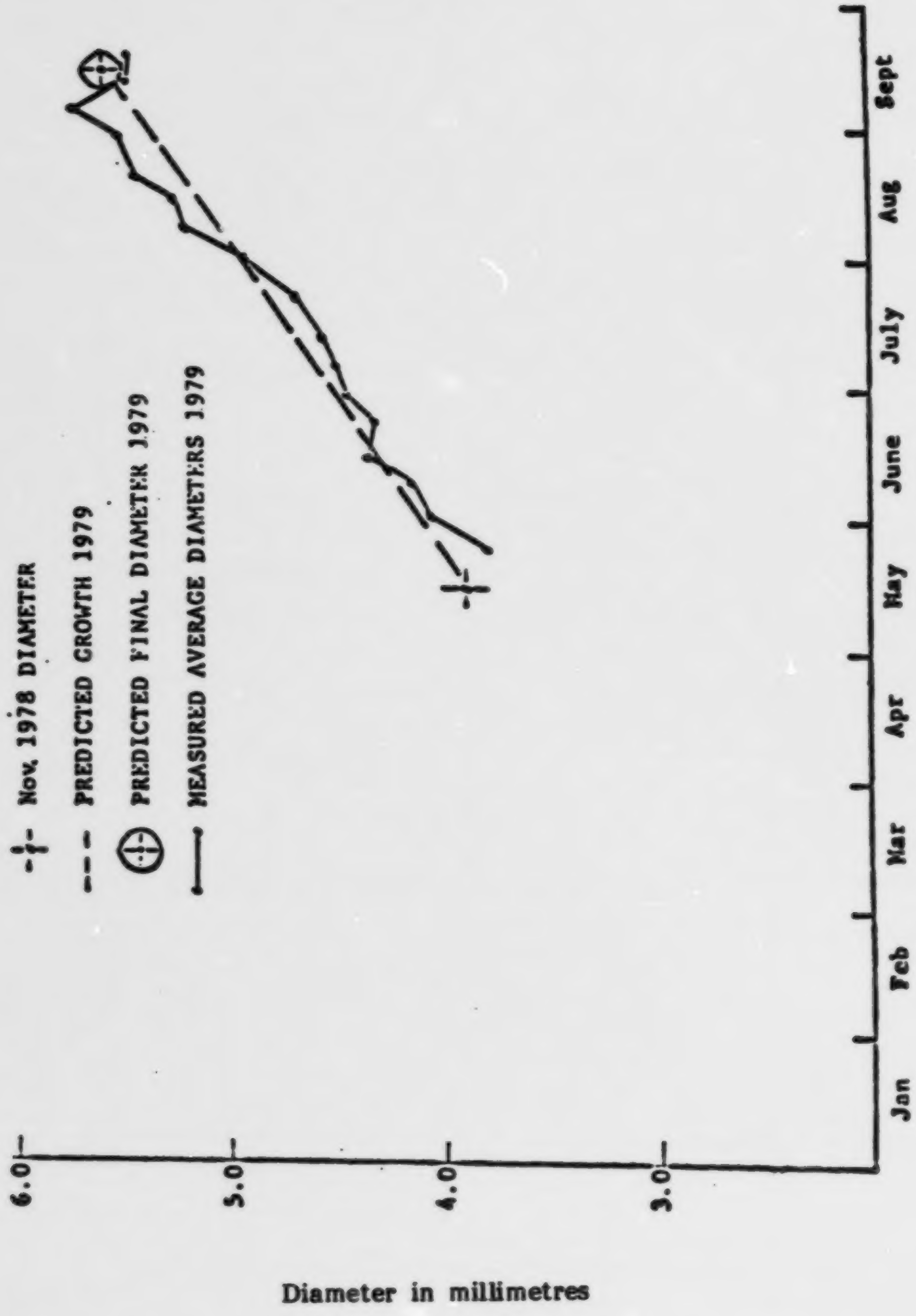


Fig. VIII-7: White spruce (3+0) comparison of diameter from November, 1978 to predicted growth in 1979

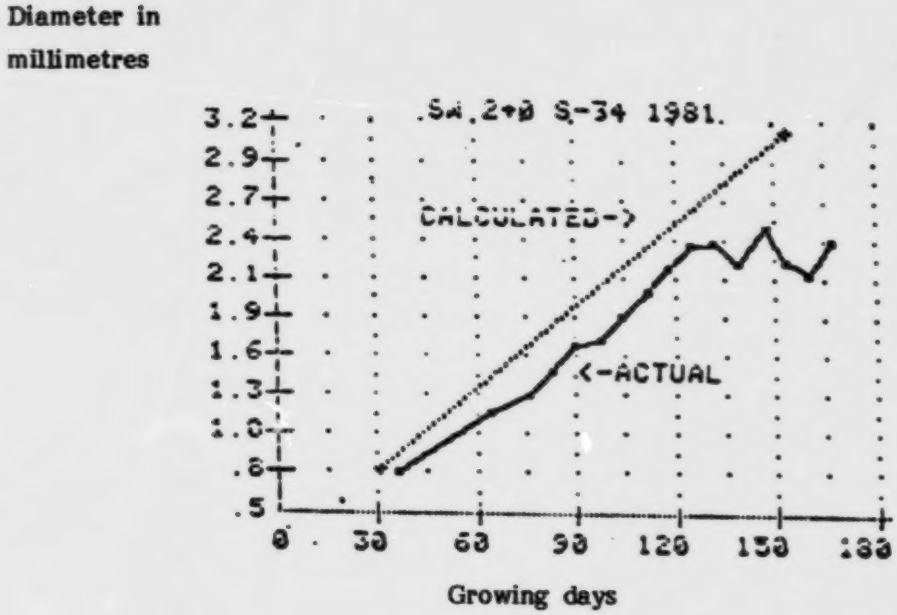


Fig. VIII-8: White spruce (2+0) 1981 actual and calculated diameter growth curves

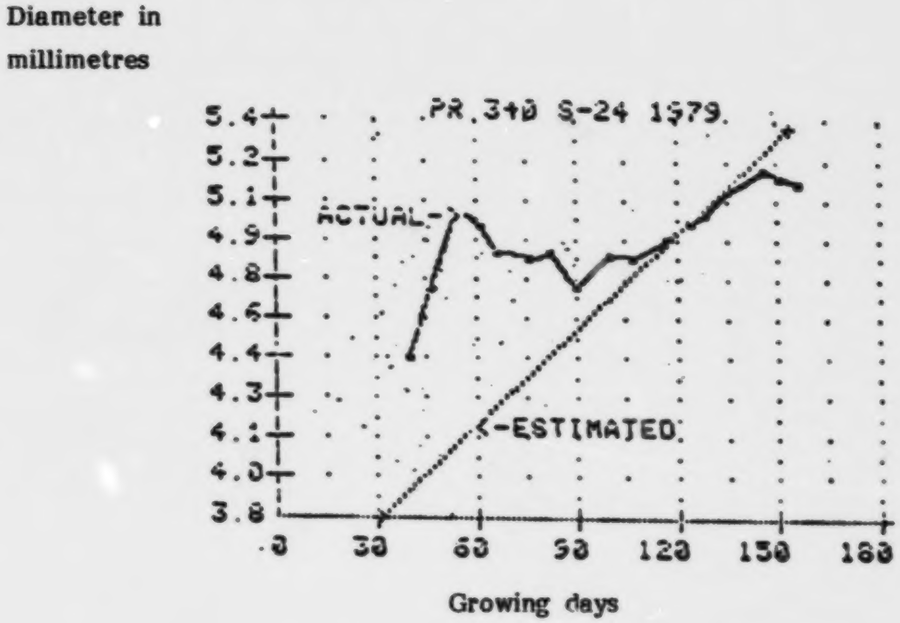


Fig. VIII-9: Red pine (3+0) 1979 actual and calculated diameter growth curves

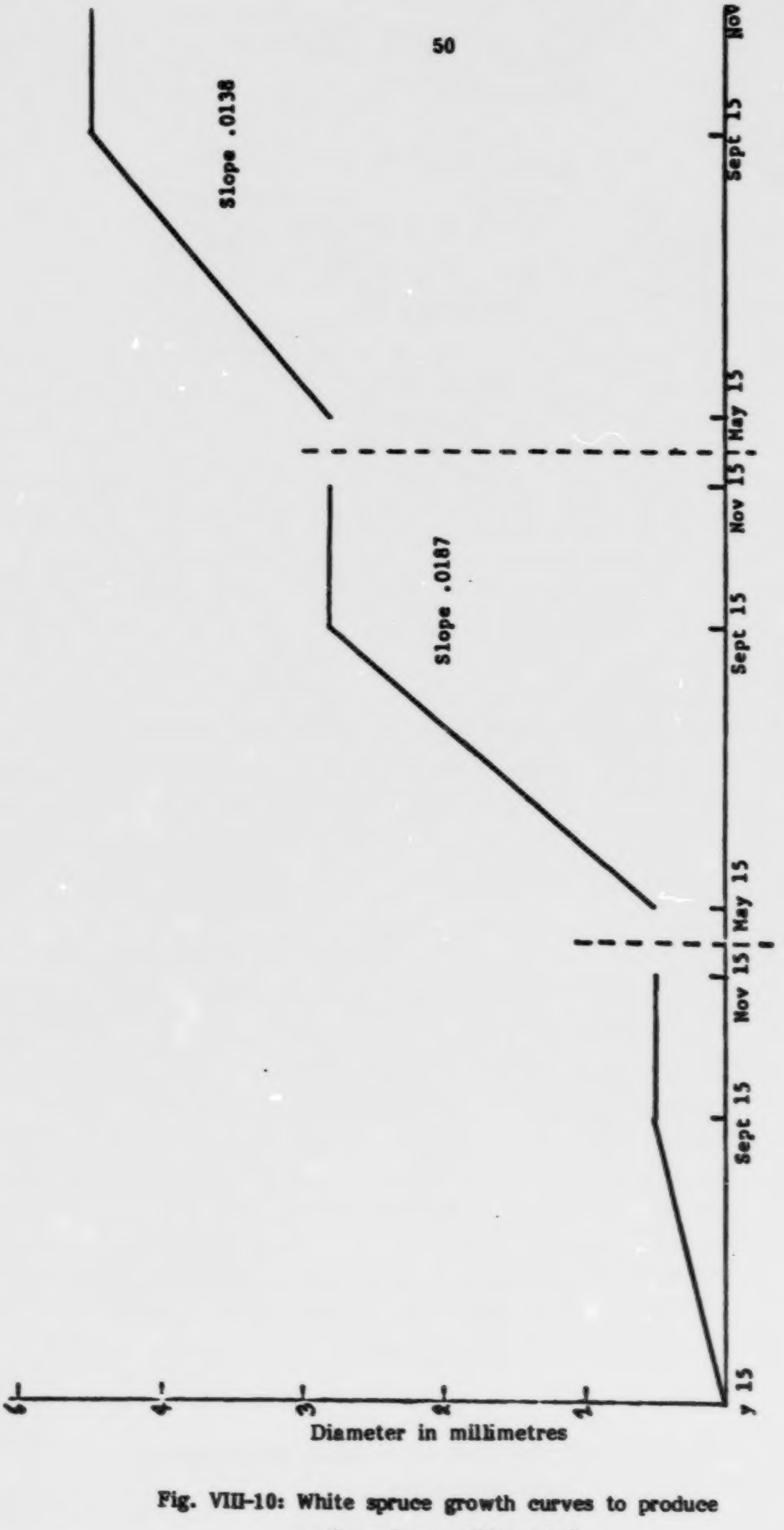


Fig. VIII-10: White spruce growth curves to produce medium-size seedling stock

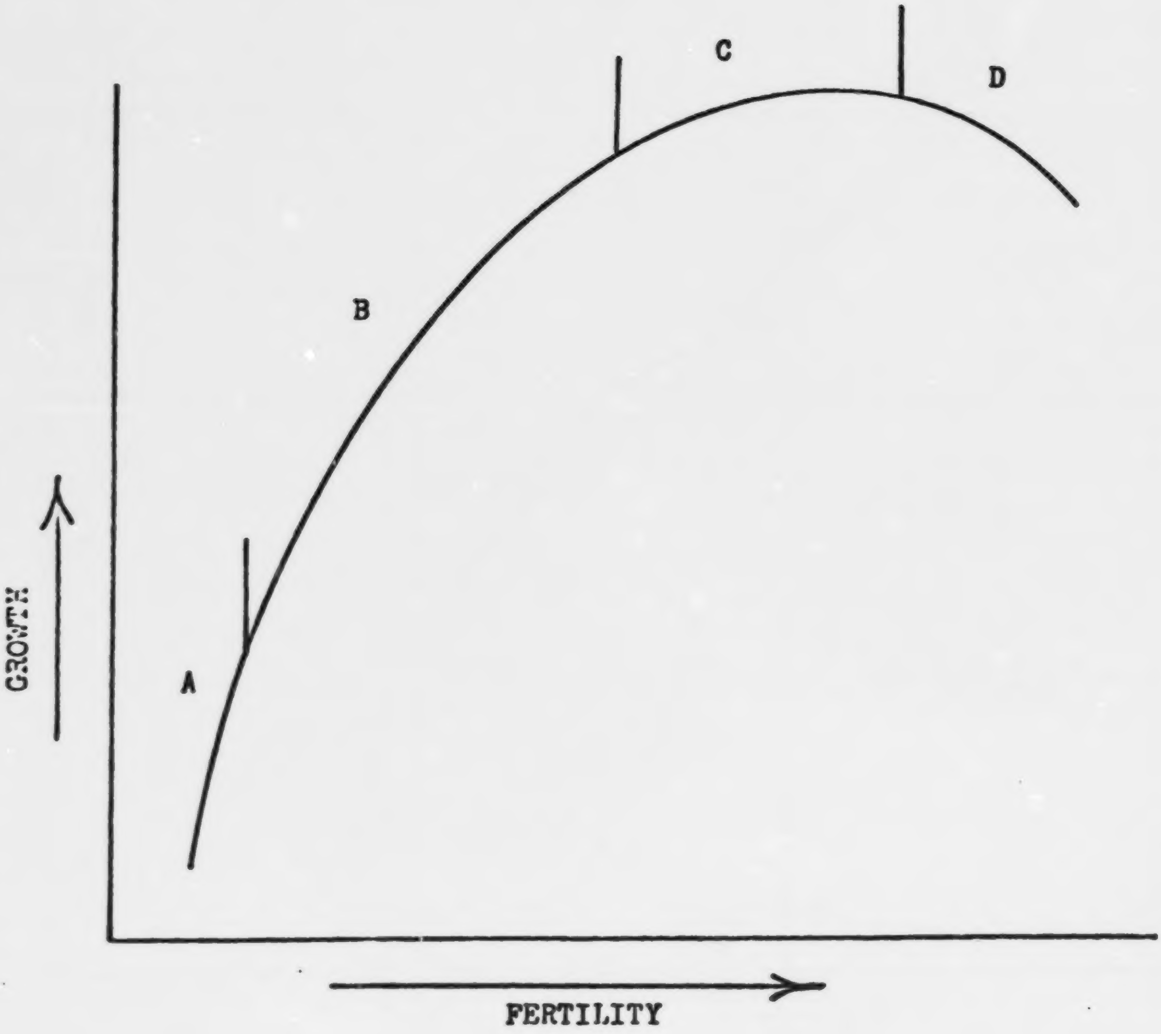


Fig. VIII-11: Hypothetical growth curve of seedlings

A. Visual deficiency. B. Hidden hunger. C. Luxury consumption. D. Toxicity.

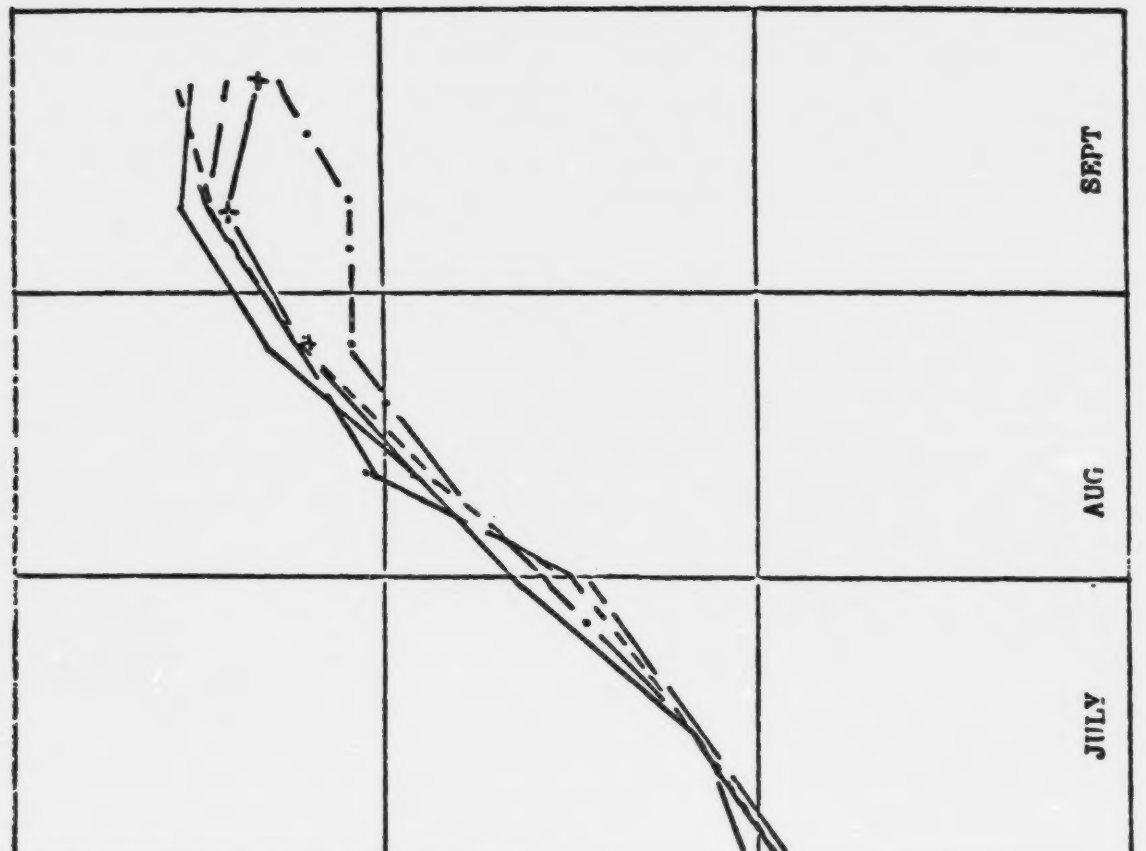


Fig. VIII-12: Fertility trials 1980 (2+0) white pine

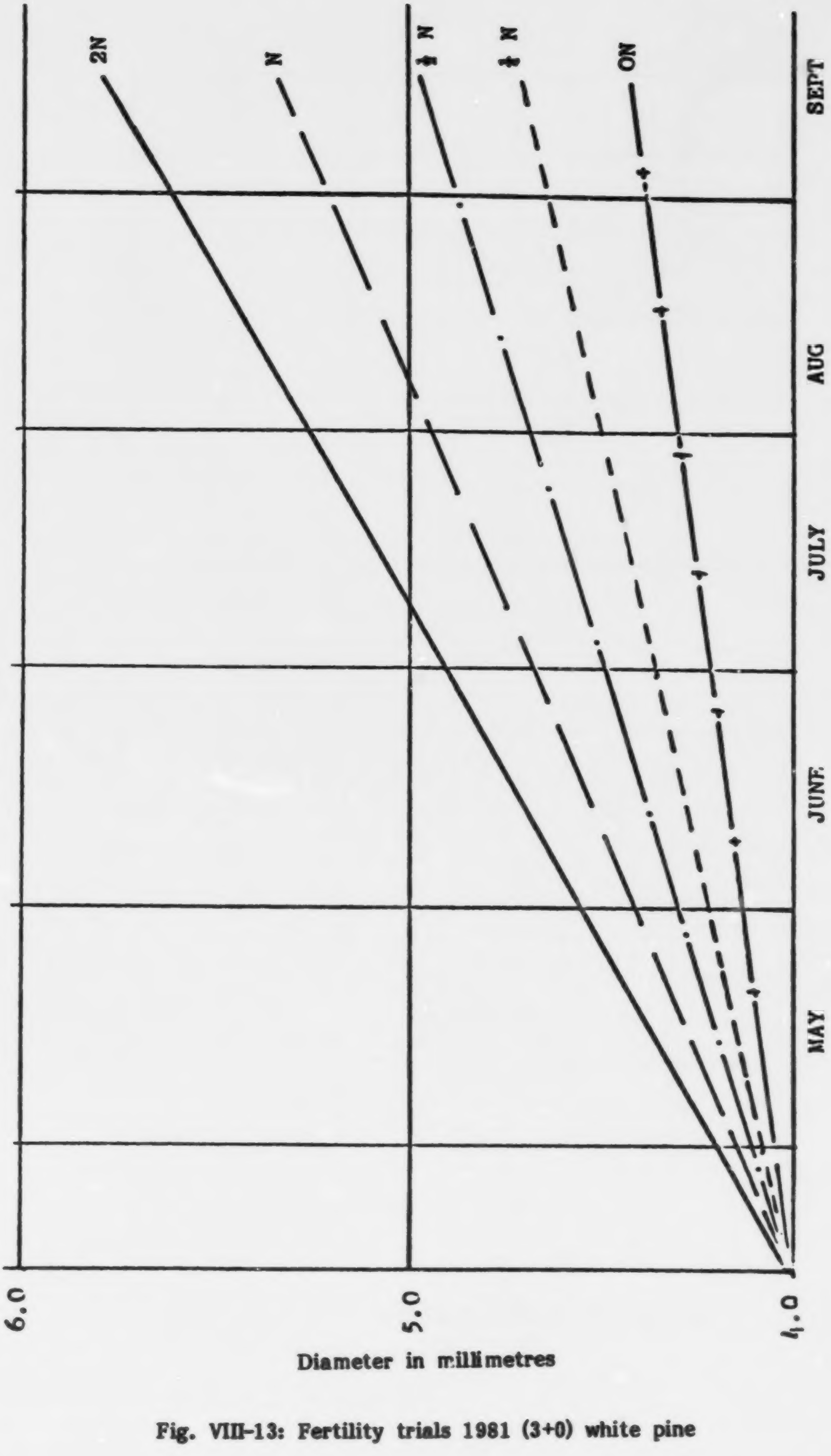


Fig. VIII-13: Fertility trials 1981 (3+0) white pine

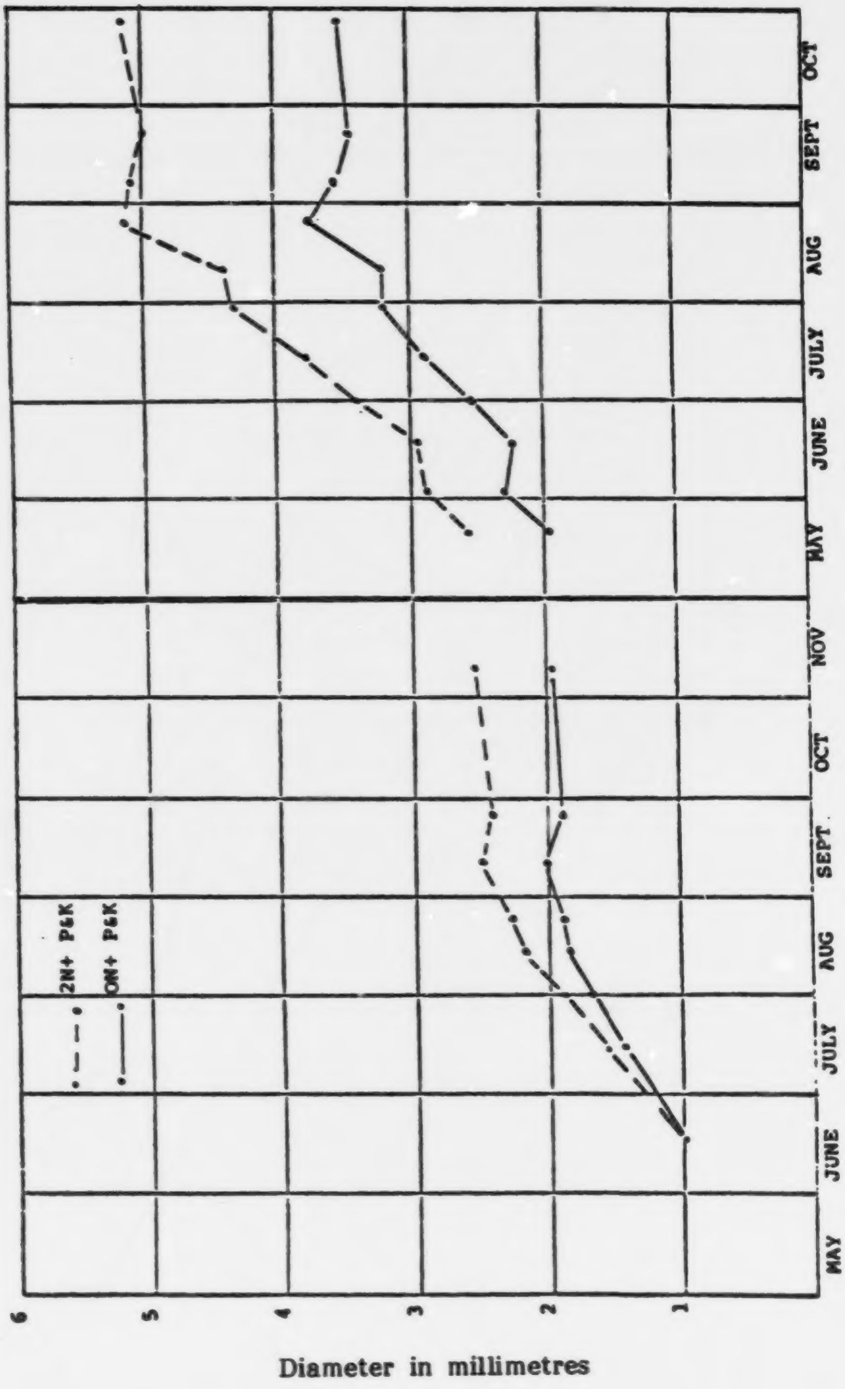


Fig. VIII-14: Fertility trial 1981 (2+0) white spruce and 1982 (3+0) white spruce

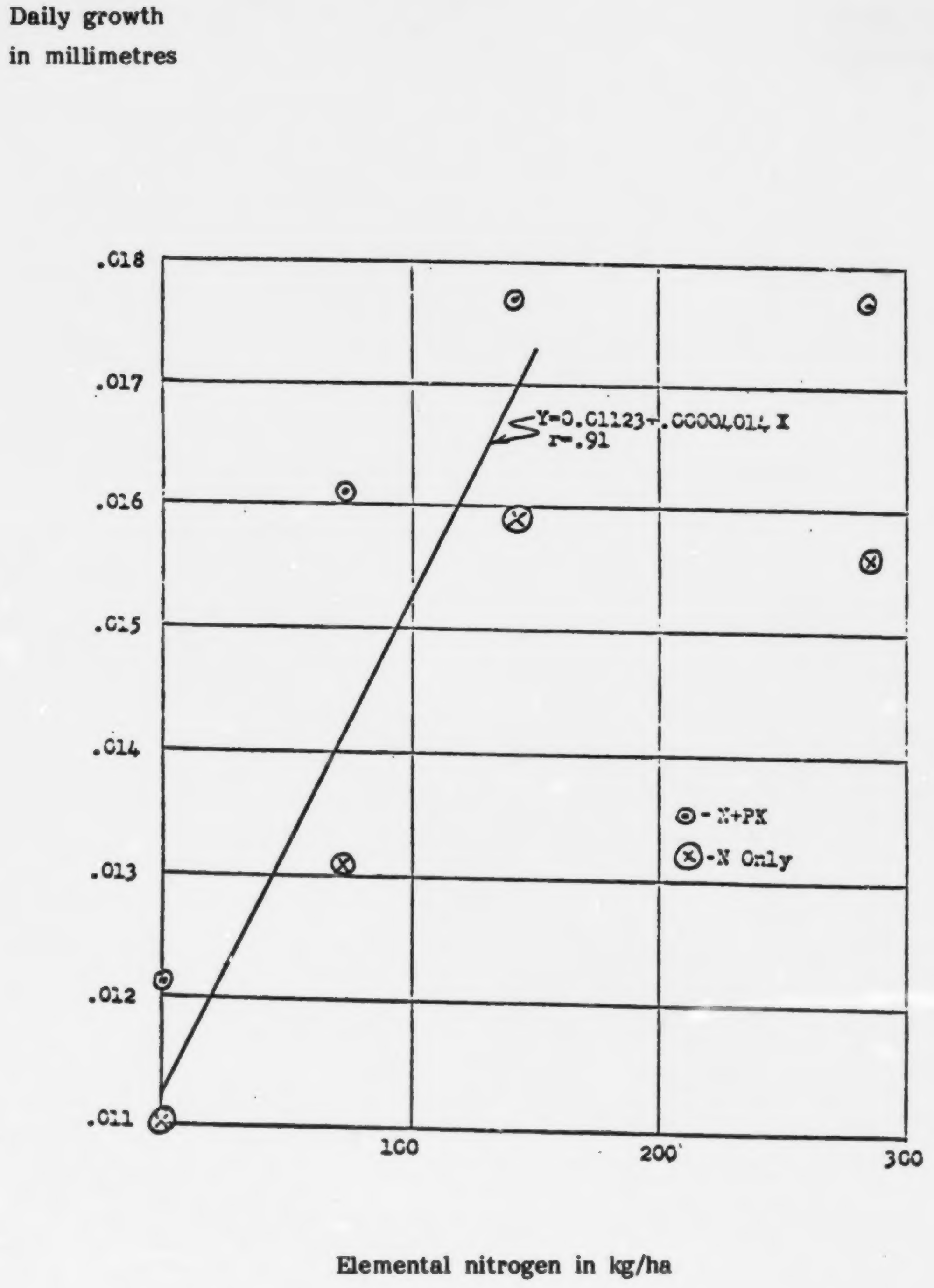
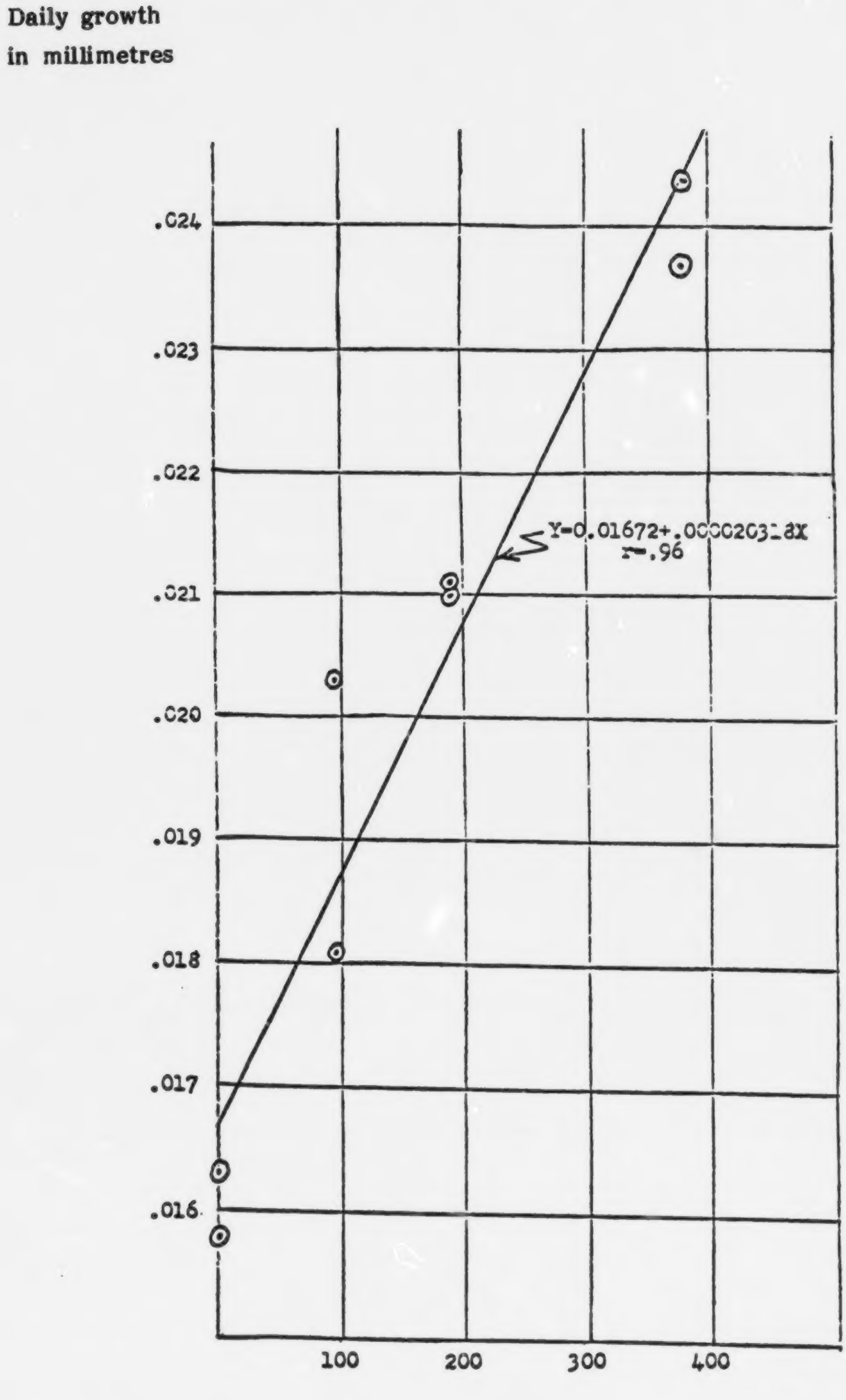


Fig. VIII-15: Fertility trial 1981 (2+0) white spruce



Elemental nitrogen in kg/ha

Fig. VIII-16: Fertility trial 1982 (3+0) white spruce

Table VIII-1: Diameter growth prediction results

Species	Age	Compartment	Measured November Diameter	Calculated September Diameter	Actual Diameter	Percentage of Error
			1979			
PNS	3+0	H-18	3.50	5.26	5.07	- 3.6
PNRE	3+0	S-24	3.88	5.37	5.15	- 4.1
PIG	3+0	H-18	3.88	5.59	5.46	- 2.3
			1980			
PNS	3+0	H-20	2.67	4.43	4.42	0
PNRE	3+0	S-22	3.04	4.53	4.28	- 5.5
PIG	3+0	S-33	3.66	5.37	5.79	7.8
			1981			
PNS	2+0	T-74	1.08	3.19	2.83	-11.3
PNRE	2+0	S-01	1.21	2.92	2.97	- 1.9
PIG	2+0	S-34	0.80	3.13	2.39	-23.6
PNS	3+0	S-32	3.56	5.31	5.21	- 1.9
PNRE	3+0	S-31	3.66	4.80	4.85	1.4
			1982			
PNS	2+0	T-64	1.07	3.14	2.65	-15.6
PNRE	2+0	S-24	1.15	2.83	2.16	- 8.8
PIG	2+0	S-21	0.85	3.13	3.08	- 1.6
PNS	3+0	H12/15	2.77	4.50	4.86	8.0
PNRE	3+0	S-01	2.85	4.75	5.18	9.1
PIG	3+0	S-34	2.24	4.06	4.45	9.6

Table VIII-2: Summary (3+0) white spruce fertility trials compartment S-34, 1982 (lab measurements)

Treatment	Diameter (mm)	Height (cm)	RAI (cm^2)	Dry Weight (gm)	Top/Root Ratio
2N+PK	5.30a	31.56a	46.58a	7.43a	3.01
2N	5.29a	30.12ab	47.57a	6.94ab	3.04
N+PK	4.83b	29.12ab	40.95abc	5.93abc	3.12
N	4.81b	28.84ab	43.28ab	6.06abc	2.82
0.5N+PK	4.37c	24.22c	45.52ab	5.12cd	2.78
0.5N	4.07c	24.89c	34.46bcd	4.44d	3.09
0N+PK	3.63d	20.98d	32.07cd	3.42e	2.99
0N	3.60d	20.61d	30.60d	3.00e	2.99
	†	†	*	†	NS

† Significant at 0.1%
* Significant at 1%
NS Not significant
Figures followed by the same letter do not vary significantly

Table VIII-3: Estimating the amount of elemental nitrogen to apply to yield a desired growth curve slope for 3+0 white spruce

Assumptions

White spruce 2+0 November diameter is 2 mm (small).

Aim is to produce a 3+0 September 15th diameter of 4.5 mm (medium).

The growing season is 154 days (April 15 to September 15).

The 2+0 November diameter will equal the 3+0 May 15 diameter.

Daily growth (slope of the growth curve) varies with the amount of elemental nitrogen applied, according to the formula $Y = 0.01672 + 0.000020318\ X$, where Y = daily growth and X = kg/ha of elemental nitrogen applied (Fig. VIII-17).

Calculations

The estimated May 15 diameter will be 2 mm. The increase in diameter required to meet target of 4.5 mm is 4.5 mm - 2.0 mm = 2.5 mm.

May 15th is 31 days into the growing season. Number of days left to grow is 154 - 31 = 123 days.

Daily growth required is 2.5 mm / 123 days = 0.02033 mm/day.

Substituting in the regression formula, the amount of elemental nitrogen required is $X = Y - 0.0167/0.000020318 = 178$ kg/ha.

Under Orono's fertilizer regime this amount of nitrogen would be applied in five equal applications from May to September.

Table VIII-4: Summary 1+0 fertility trials
Orono nursery, 1982

Treatment	Diameter (mm)	Height (cm)	RAI (cm^2)	Dry Weight (gm)	Top/Root Ratio
			White Spruce		
0N	0.84b	3.65b	2.51b	0.08c	2.11
0.5N	0.95a	4.04a	3.10a	0.10b	2.07
N	0.99a	4.46a	3.29a	0.12a	2.32
2N	0.97a	4.37a	3.37a	0.11ab	2.04
	*	*	*	#	NS
			White Pine		
0N	1.26b	4.65	8.46	0.33	1.34b
0.5N	1.29b	4.88	8.06	0.34	1.52b
N	1.42a	4.94	9.31	0.40	1.83a
2N	1.45a	5.13	8.94	0.41	1.83a
	*	NS	NS	NS	#
			Red Pine		
0N	1.07	4.03	4.60	0.20	2.03
0.5N	1.08	4.20	4.75	0.20	1.96
N	1.10	4.39	5.64	0.23	2.11
2N	1.13	4.35	5.36	0.24	2.05
	NS	NS	NS	NS	NS

* Significant at 1%
# Significant at 5%
NS Not significant
Figures followed by the same letter do not vary significantly

Table VIII-5: Root pruning and root wrenching
2+0 red pine, compartment S-01, 1981

1981 2+0 Measurements

Treatment	Height (cm)	Diameter (mm)	RAI (cm^2)
Operational 5 in prune	12.7	3.41a	25.1b
Shallow 2-3 in prune	13.7	3.39a	28.4b
Shallow + 3 wk. wrench	14.3	3.36a	39.8a
Shallow + 6 wk. wrench	13.3	3.06b	29.3b
	NS	‡	*

2+0 Post planting growth and survival

Treatment	Survival Percentage	Current Height (cm)
Operational 5 in prune	98.4	14.07a
Shallow 2-3 in prune	94.8	12.52b
Shallow + 3 wk. wrench	96.0	9.13c
Shallow + 6 wk. wrench	95.2	8.54c
	NS	†

1982 3+0 Measurements

Treatment	Dry Weight (g)	Height (cm)	Diameter (mm)	RAI (cm^2)	Top/Root Ratio
Operational	13.45a	37.25a	5.67a	42.46b	7.43a
Shallow	9.32b	32.86b	4.81b	55.19b	5.89b
3 weeks	9.95b	28.66c	4.87b	69.23a	3.95c
6 weeks	8.24b	28.46c	4.60b	51.39b	4.29c
	*	†	†	*	†

NB: Seedlings were not pruned in 1982 (3+0 year).

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† Signficant at 0.1%
* Significant at 1%
‡ Significant at 5%
Figures followed by the same letter do not vary significantly

IX

CONTRACTING

Antoinette Wells

The theme of today's session is "management considerations" and within the broad context of this topic, I have been asked to address this conference on the subject of contracting. Today, I wish to speak briefly to you on some of the problems which we face in contracting out for services from the private sector.

As you are all well aware, contracting is becoming an increasingly important method of delivering programs and services within the Ministry. The current salary constraint, coupled with the government policy thrust towards privatization, has meant that Ministry management has been forced to turn to the private sector to carry out many of the Ministry's activities. This is a major departure from historical practice, where Ministry functions are traditionally carried out internally. This transition has not been effected without problems.

The shift from the use of internal resources to external sources of supply has been hampered by two things: (i) there is a lack of experience in the private sector, particularly in the service area related to forest management; (ii) there is a lack of internal expertise in developing, implementing, and managing contracts.

The first problem — lack of an adequate number of competent suppliers — is the most difficult to overcome, and will be remedied only over a long period of time. In the case of private container stock production, the dearth of qualified contractors and the insufficient production capability in the private sector were resolved only by the artificial creation of a pool of supply with very high capital subsidization. In this instance we are not simply growing trees; we are producing nursery facilities and experienced growers.

With respect to the second issue — lack of internal expertise in developing, implementing, and managing contracts — we are attempting to minimize some of the difficulties by (i) educating staff by means of seminars, courses, etc., on contract management; (ii) developing standard form contract documents, guidelines, and procedures for securing services; (iii) providing in-house advice and consultation on contract methods and problems.

We hope that with continued efforts in this direction, the contracting process will become easier for you, as project managers, to deal with. As I stated earlier, the transition to privatization has not been without its problems. I would like to highlight for you some of the common concerns which are expressed in relation to contracts.

1. "I don't have as much control with a contractor as I do with my staff."

This is quite true. When contracting for services you relinquish control over the performance of the work to the contractor. The control which you exercise is over what the contractor does, not over how he does it. This is why well-developed specifications and standards for the work are an essential element of good contracts.

2. "It is a lot easier to administer staff than to administer a contract."

Contracts necessarily involve a different style of management and different procedures than administering staff. Most managers are familiar with procedures for administering staff because these have developed over time and are generally well institutionalized. Contract procedures, on the other hand, are in the developmental stages and, given the limited exposure of managers to the contracting process, they understandably appear more burdensome and restrictive.

As to the point about it being easier to administer contracts; those of you who have ever had to terminate a contract will confirm that it is an involved process. Compare this, however, to the process required to terminate a regular staff member whom you feel is incompetent.

3. "I don't understand all the legal jargon in these contracts."

I don't think it is a necessary part of good contract administration for project management to have to understand the legal rationale behind all the provisions in an agreement. Certain clauses, known as "boilerplate clauses," are included in most contracts to address specific common law principles. These are most often found in the "general" section of agreements. What you do need is a basic understanding of the nature of the contractual relationship and the obligations which the agreement imposes on the Crown and on the contractor. If it becomes imperative for you to have specific legal provisions interpreted, you have recourse to legal advice for this.

4. "Contracting for services is more time-consuming and more expensive than having the service performed by your own staff."

This is a blanket statement and, like most blanket statements, suffers from too many exceptions to be credible. The process of personnel administration in any organization or unit consumes a large amount of management time; from the hiring process to payroll to staff relations matters, the supervisor is involved. That is not to say that there is less staff time employed in effectively managing contracts, it merely points out that the complaint often conveniently ignores the time consumed in administering employees.

With respect to the assertion that contracting with the private sector is more expensive; there is a common flaw in this assertion. Our internal costs for performing services do not translate well into the private sector. While we have information on the cost of growing tree seedlings, drawn from the expenditures of our various nurseries, these costs are not directly comparable to those in the private sector without serious adjustments. For example, overhead costs such as professional fees and capital costs, which constitute important components of the prices which we receive from the private sector, are not calculated in our internal costs. Our costs are derived from expenditure reports for salaries, transportation, services, supplies, and equipment; they do not include all the additional "soft costs" of support and the costs of capital. Comparisons of MNR costs with those of the private sector can be misleading.

5. "I don't have the flexibility with contracts...."

Contracts can both diminish and enhance your flexibility in managing resources. On one hand, a contract is a legal commitment which cannot be switched on and off expeditiously to meet changing circumstances. This is particularly true of multi-year agreements. On the other hand, from a work-programme planning perspective, contracts permit you to retain flexibility in allocating "B" salary dollars to critical activities while securing private sector services to perform other functions. In addition, some flexibility can be built into the contract documents which will give project managers room to manoeuver in altering the specifications and terms of the project.

6. "I feel uneasy about contracting because there are all sorts of horror stories about contractors."

There are numerous instances where nonperformance on the part of a contractor has resulted in failure to meet output commitments, poor public relations for the Ministry, and lengthy and complicated termination settlements. Sometimes this is the result of a systemtic problem (i.e., no stable qualified contractors, etc.) and sometimes it is the result of poor contract management or simply poor contracts. One positive aspect of problem contractors is that our contract documents and procedures have become more sophisticated in line with our experience.

The best contracts and the most explicit procedures, however, afford little protection from recalcitrant contractors. Under these circumstances, the most you can hope to recover is the marginal compensation afforded by bonds, holdbacks, etc.

In the final analysis, horror stories and all, contracting out for supply of goods and services is government imperative. It is your responsibility to ensure that the risks entailed in this process are minimized and to manage both the failures and the successes.

7. "I wish I didn't have to choose the low bidder...."

Government policy on competitive purchasing outlines four basic principles to which the purchasing process in this Ministry adheres: (i) all interested suppliers, (ii) fair opportunity, (iii) lowest responsible bid, and (iv) objective selection criteria.

The lowest bid on a tender may not necessarily be the lowest responsible bid, and it is up to you to prepare a defensible position in respect of your selection. If you spend time developing good tender documents, setting out the experience required and other ancillary criteria, then choosing and defending the selection is an easier task. Either you spend the time at the outset to prepare adequate documentation and to justify selection of other than the lowest bidder, or you accept the risk of selecting an irresponsible or inexperienced contractor with the concomitant possibility of nonperformance of the contract.

8. "It is almost impossible to change a contract once you have signed it...."

Contracts are written agreements between two parties that are crystallized at a given point in time. The essence of a contract is agreement, and there is nothing to prevent you from changing the terms and conditions of an agreement once it has been signed, provided that the changes are mutually agreed upon. The only time you have a problem changing a contract is when one party doesn't agree. Then it becomes a matter for negotiation. Similarly, you can waive your right to hold a contractor to performing an obligation if you choose. Contract amendment can be a simple procedure — as simple as writing a letter and obtaining written agreement from the contractor. You should have changes confirmed in writing, to protect the Ministry in the event of a future disagreement with the contractor and for audit purposes should this have an effect on the nature or value of the service performed. For complex and high dollar contracts, we generally use amending agreements to secure our position.

In closing, Mr. Chairman, if the objective in having me speak to this conference was to offer solutions to problems in contract management, then I have not succeeded in the task. I have only been able to identify some of the difficulties and misconceptions surrounding the process. I am optimistic, however, that as we gain experience as an organization in privatizing some of our activities, the contracting process will become easier, more efficient, and more effective. In the interim, I cannot offer a panacea — only limited assistance in developing and implementing your contracts.

X

QUALITY CONTROL IN TREE LIFTING

Grant Leeder

Contract tree lifting was initiated at the G. Howard Ferguson Forest Station in the spring of 1980. Because we had trouble assessing the quality of the contractor's tree lifting each day, we developed the following system to assess the quality of the contractor's work as well as that of MNR crews.

There is one quality control person for each lifting crew; crews are headed by an experienced MNR crew boss. The quality control person samples 100 trees in the morning and 100 in the afternoon. The trees are bundled in tens, not the usual 25, and the sample is obtained by taking ten trees (or one bundle) from ten bags. Results of the samples are recorded on the Tree Lifting Quality Assessment Sheet (Fig. X-1). For every poor-quality tree 1% is deducted. The percentages are then averaged, and a deduction of trees is taken from the total lift for that day. For example, if the average percentage for the day was 90, and the contractor lifted 200 000 trees, 10% of the 200 000 trees would be deducted from the daily total.

The quality control person fills out a Stock Quality Checklist (Fig. X-2). This keeps us up-to-date on how the crew is performing. Although we do monitor our MNR crews, we do not make any deductions, because if the quality drops we have the right to dismiss the poor-quality tree lifters.

A contractor has occasionally dropped to 86%, or reached 100%, but the average is around 95%. We are satisfied with the performance of the system. At our post planting meeting with the Districts this spring, the quality of tree lifting at the G. Howard Ferguson Forest Station was reported to be very good.

G. Howard Ferguson Forest Station
Tree Lifting Quality Assessment Sheet

Date: ______________________ Foreman: ______________________

Compartment: ______________________ Signature: ______________________

Site Region: ______________________ Contractor: ______________________

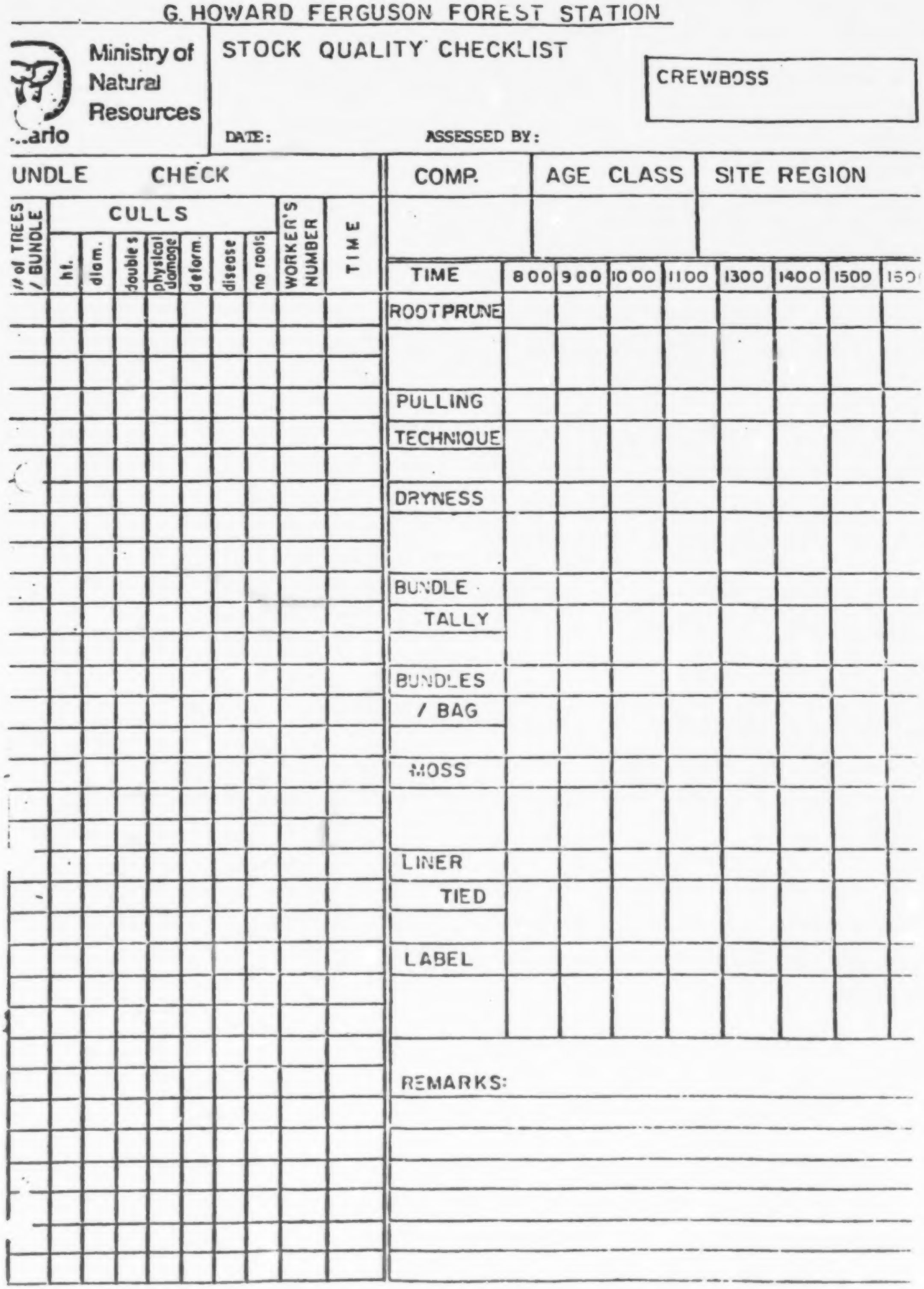
Species: ______________________

Age Class: ______________________

Bag No. of Bundles	Discr. In Count Per Bundle	Height (Minimum)	Stem Diameter	Growth Deformities	Physical Damage	Disease Related Damage	Percentage Total
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
% A.M.							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
% P.M.							
AVER. %/day							

Comments: Assessed By:

Fig. X-1: Tree lifting quality assessment sheet



G. HOWARD FERGUSON FOREST STATION

Ministry of Natural Resources
ario

STOCK QUALITY CHECKLIST

CREWBOSS

DATE:

ASSESSED BY:

UNDLE CHECK

# of TREES / BUNDLE	CULLS							WORKER'S NUMBER	TIME
	ht.	diam.	doubles	physical damage	deform.	disease	no roots		

COMP.	AGE CLASS	SITE REGION

TIME	800	900	1000	1100	1300	1400	1500	16
ROOTPRUNE								
PULLING TECHNIQUE								
DRYNESS								
BUNDLE TALLY								
BUNDLES / BAG								
MOSS								
LINER TIED								
LABEL								

REMARKS:

Fig. X-2: Stock quality checklist

XI

MANAGING UNDER CONSTRAINTS

D.J. MacNaughtan

A better title might be, "How to Get Something for Nothing, or at Least Very Little"; and with this statement in mind I want to share with you how we were able to arrange for over $700 000-worth of free or inexpensive work to be done at the G. Howard Ferguson Forest Station this year.

The secret is "special employment programmes." With budgetary cutbacks and constraints an everyday occurrence, these special programmes have been the key to filling in the gap in our work programme, as well as allowing us to carry out work we would otherwise not be able to do.

Here is a summary of the programmes with which we were able to involve ourselves.

The Forest Employment Simulation Programme (FESP)

The first and largest project under this programme is sponsored by the town of Kemptville. There are 25 participants who will work from January to December, 1983. The project is valued at $419 000.

The second project was sponsored by Green Things of Brockville, a private contractor. This project was relatively short, starting in January, 1983 and terminating March 31st. There were eight participants and the project was valued at $56 000.

The final FESP project is sponsored by Winston McEwen Power Line Construction, another private contractor. This project, which started in April, 1983 and will run until December, employs eight participants and is valued at $107 000.

FESP projects must have an outside sponsor and work carried out must be forestry-oriented. The nursery has no direct involvement in the crews or administration of the project; we only assign the work. Participants are selected by the sponsor in co-operation with Canada Manpower, and are paid by CEIC. The Canadian Forestry Service pays the operating and administrative costs. Participants in the FESP program must be eligible for UIC benefits.

COED/NEED Project

Although this programme has temporarily run out of funds prior to our project being approved, it will provide 318 man-weeks of work and have a direct benefit to the nursery at a value of $122 166. Work to be done is nursery research, construction of growing frames and water tracks, traffic diversion and landscaping around the headquarters, and the collection of sphagnum moss.

The Ministry of Natural Resources will hire the staff and supervise the project directly. The participants hired under the project are "exhaustees" — persons who have exhausted all their benefits.

Experience '83

Our 1983 Experience programme, involving 12 participants, will commence June 21st and continue through to the end of August. The Experience programme is designed for young people ages 16 to 24. The work is varied and covers all aspects of nursery work. The value of the Experience '83 programme at the G. Howard Ferguson Forest Station is $20 000. MNR hires for and directs the Experience programme directly.

I have outlined three programmes here that are available to all nurseries in the province. However, we are not necessarily limited to these three possibilities. New programmes seem to emerge regularly and I suggest that all of them should be explored.

I must admit that initially I was apprehensive and skeptical; but this was short-lived. Once the programmes started they tended to carry themselves.

In conclusion, I would like to advise you all to offset the shrinking funding of your programmes by thinking "special employment programmes." It is one of the few opportunities we have to get something for nothing and, in our small way, help get Canadians back to work.

XII

PROVINCIAL SITUATION

K.H. Reese

Demand for Stock

The production targets for bare-root stock are at approximately 87 million seedlings. Owing to transplanting, nursery capacity is limited and for the near future bare-root production targets will remain at this level. Growth in production, however, will be with container stock, and targets should reach 70 to 90 million seedlings within the next five years. In 1983 we will purchase 30 million containers and grow some 12 million container stock in our own facilities. This growth is due to the increasing demand for containers in Forest Management Agreements (FMA) which, for several reasons, prefer this form of planting stock. Although five more FMAs are to be signed this year, most of those requiring large amounts of planting stock are now in place.

Agreements with Private Growers

Stock production agreements are developed by seeking proposals for a set volume of containers over a five-year period. Of the agreed-to capital costs, 50% are paid at the time of construction; the remaining 50% are spread over the five-year contract period, at the end of which the contractor owns the greenhouses. This contracting is probably one of the more significant steps in stock production since the beginning of the tubed seedling project in the 1960s.

There are now 19 private growers with contracts requiring between two and six million nursery stock annually. Discussions are underway with other potential contractors. Currently there is enough greenhouse area to produce some 70 million container seedlings, assuming the increased use of double cropping. However, some upgrading in heating will be required. Most houses are double poly, Quonset style, but a few gutter-connected ranges have been built and most are suited for only one crop per season.

Reasons for Container Demand

In the early discussions about FMAs it was thought that companies would not choose tree planting because of the high cost; hence, no budget was considered. Also, it was thought that planting stock requirements could be obtained from the supplies which the Crown was already planting on the FMA areas. As the "free-to-grow" formula became better understood, it became evident that industry would not choose low-cost treatments, because any retreatments would be at their expense. Thus, with each new FMA the demand for container stock has accumulated. As a result, in 1984 the Forest Resources Group will have to find some $10 million to purchase seedlings from private growers.

Specifications for Container Stock

The FMAs usually specify container stock weighing between 300 mg and 500 mg. To date, the growers have been quite successful at meeting this quality standard. The required quantities have largely been achieved in total, the shortages of one grower being made up by the overruns of another.

Research outplantings in jack pine have demonstrated that the specifications for container stock result in plantations equivalent to bare-root stock performance. For black spruce on upland sites, preliminary five-year results indicate that for container seedlings, size standards should be increased some four times in order to achieve a performance similar to that of bare-root stock. These standards will, no doubt, evolve as additional data become available.

Future Developments

- Research plantings are required on additional sites that are not yet included in stock size trials, in order to refine specifications.
- Additional research work is required on the conditioning of containers for summer planting.
- Hardening procedures for overwintering seem to be operational and successful. It is not clear whether this will result in reliable outdoor storage of containers during the winter, or whether refrigerated storage is ultimately required.
- It is not clear whether future expansion will, in the long run, involve adding new growers or enlarging the facilities of existing growers. Competitive bids for the next five-year cycle will, no doubt, result in a reduction in the number of growers.

XIII

CONTRACTING CONTAINER STOCK PRODUCTION

Antoinette Wells

In December, 1981 the Ministry entered into the first three five-year contracts for container stock production with private growers in Northern Ontario. Today we have 19 growers under this type of container stock contract — five in the North Central Region, ten in the Northern Region, and four in the Northwestern Region. In addition, we have one grower, Walsh Nursery Ltd., in the Eastern Region on a one-year growing contract with annual renewal options. With the exception of the grower in the Eastern Region, the privatized container stock production programme has been an exclusively Northern Ontario programme.

The private grower stock programme for containerized tree seedlings developed as a result of the increased demand for containers for plantings generated by the FMAs. Faced by a lack of production facilities in Northern Ontario with the capability to produce the levels of container stock required to feed the planting programmes of the FMA companies, the Ministry had to go to the private sector for container production. In order to establish the number of facilities required, the Ministry developed five-year long-term contracts which permit private growers to effectively write off the capital and operating costs of new facilities over the contract term as a component of the price per thousand seedlings.

At present the Ministry has an estimated total capital commitment of approximately $10 million in development of private container facilities in Northern Ontario.

The container stock production contracts in Northern Ontario are illustrative of the kind of speed and flexibility which contracting out services has for management of our programmes. In December of 1981 there were no five-year private container stock production contracts in Northern Ontario; during 1983/84, 19 growers are targeted to produce in excess of 30 million tree seedlings. The process has taken us about three years to implement — rapid implementation, which would have been impossible without private sector involvement and large capital subsidization.

While there have been benefits to contracting out this service, there have also been problems. From a corporate perspective, foremost among these is the strain which the commitments to purchase stock have had on our budget. Our programmes (i.e., site preparation, planting, and nursery operations) have been squeezed as a result of the impact of the container stock agreements.

In the narrower perspective, there have been difficulties in developing and implementing these contracts, and with the stock that is being produced. These are the growing pains of progress, and these are the aspects of container stock production I will highlight here.

Generic Agreements

Because of the complexity of the procedure and the number of dollars involved in these agreements, we have developed a set of relatively sophisticated contracts with the private growers. There are now four sets of standard contract documents in place: (i) a generic agreement for filled and seeded paperpot stock production; (ii) a generic agreement for unfilled and unseeded paperpot production; (iii) a generic agreement for Spencer-Lemaire production; and (iv) a generic agreement for straight container stock production without capital payments. In addition, we have a standard form extension agreement for each of the above which is used for annual renewals.

The standard contracts are undergoing a continual process of review. As the Regions and the growers become more experienced in dealing with contracted stock production, deficiencies in the agreements become apparent and they are changed, upon mutual consent, on an annual basis, to remedy any serious problems. As the contracts are still in their infancy, some problems may not yet have surfaced; however, there are a number of cases where changes, based on our experience, have been effected.

Stocking levels: Our original paperpot agreements called for 50% stocked cavities in a tray before repacking was required. This has since been increased to 75% as a result of the need for consistency with FMA requirements. There has been little impact in terms of price because growers were generally producing in excess of the 75% stocking requirement.

Seed viability: In the Eastern Region's contract, a seed viability chart and testing provisions were incorporated into the agreement to eliminate problems of poor stocking incurred by overestimating seed viability. The thinning of multiple germinants is labour-intensive and has a direct effect on operating cost. By incorporating these provisions, the contractor assumes responsibility for inaccuracies which affect his earnings.

Payment schedule: The progress payment provisions were altered in the NCR agreements to tie payments in with inventories. One original grower resisted the change and is continuing to be paid under the old formula.

The above are a few examples of the types of amendments which have been made to these contracts. The danger we face in capriciously altering our agreements is that regional disparities will develop. While there is no intention to fetter the Regions' flexibility in setting the terms and conditions of this programme, we are careful to ensure that growers with long-term agreements are treated equitably.

Price Structure and Renegotiation

This aspect of the container stock agreements is the most contentious and the least well understood. I have included it in my remarks to give you an idea of the rationale underlying the pricing system which we currently use.

Price Structure: The pricing structure established in the container stock production contract is designed to provide for full recovery of all capital and operating costs related to new greenhouse facilities.

(i) Capital cost. Upon entering into a five-year growing contract, growers receive a capital payment equivalent to 50% of the cost of constructing new greenhouse facilities. This capital cost payment applies only to the construction of new facilities, not to upgrading or renovating existing facilities. The balance of the capital cost and the interest on the outstanding capital balance are recovered in annual increments over the five-year term of the contract as a component of the price per thousand seedlings.

(ii) Operating cost. All annual costs directly associated with the operation of the new greenhouse facility are covered off as a component of the contract price per thousand seedlings. Typically the operating cost of the nursery facility includes materials, labour, fuel, hydro, maintenance, overhead, and interest on moneys borrowed to carry the operation. In addition, growers are entitled to a profit and risk margin on operations.

(iii) Contract prices. There are two prices set out in the agreement — a regular rate, which applies for each 1000 seedlings grown up to the production target, and an excess rate which applies to each thousand seedlings produced in excess of the production target.

The regular rate for seedlings is derived by dividing the total annual operating cost plus the annual capital cost portion by the production target, to achieve a dollar value per twelve thousand seedlings as follows:

$$\frac{\text{Annual capital cost} + \text{annual operating cost} \times 1000}{\text{Target number of seedlings}} = \text{regular rate}$$

Therefore, growers who meet their production targets and whose seedlings conform with the nursery stock standards established by the contract will fully recover all annual operating costs and the annual portion of the allowable capital costs.

The excess rate is derived as follows:

$$\frac{\text{Annual operating cost x 1000}}{\text{Target number of seedlings}} = \text{excess rate}$$

The Ministry has the option to purchase excess stock at the excess rate, but is not obligated to do so. The excess rate provides an incentive to growers to achieve the maximum stock production and to operate efficient and effective nursery facilities. Any excess stock purchased by the Crown will provide the grower with additional profits, because the full annual cost of the nursery operation is recovered on the regular rate alone.

Factors Influencing Price: The contracted price for container stock varies with the size, production capacity, and efficiency of the nursery operation. As capital and operating costs are written off over a specific production target, those growers with larger facilities and a correspondingly larger output tend to have lower prices than smaller operations. Location of the facility is also a factor in determining cost. Facilities located in outlying areas have correspondingly higher capital costs, which are reflected in higher regular rates for stock.

In some cases, growers under contract with the Ministry own and operate bedding plant or other nursery operations. This permits these growers flexibility in transferring labour crews between operations, thereby minimizing costs.

The sophistication of the grower in operating a nursery has a direct effect on prices. Those growers who have previous experience in nursery operations generally operate more efficiently than those with no prior experience. It is anticipated that the Ministry, through price renegotiations, will achieve some cost savings as growers become more experienced in nursery stock production.

Price Renegotiation: Prices for container nursery stock are renegotiated annually with each grower. The new regular and excess rates established under these renewal agreements reflect the actual costs of the individual nursery operations.

Annual price renegotiation permits the Ministry to retain sensitivity to changing economic circumstances (i.e., inflationary increases and declining interest rates), and to adjust prices to ensure equitability and efficiency.

As growers have a five-year growing commitment, the Ministry can ensure that in the absence of competitive pricing growers can justify their submitted prices. For this purpose the contracts provide for full disclosure of all the contractors' books and records.

Stock Standards

Our contracts provide for two sets of standards for container stock — dry weight and stem height. The specifications set out both minimum and optimum levels within these categories and growers are given a range within which stock is determined to be acceptable.

The stock standards set by the contracts are minimal. There have been discussions concerning the inclusion of a top/root ratio dimension but this issue has not been satisfactorily resolved. Also at issue is the subject of stock which has sustained some damage as a result of overwintering but is determined to be acceptable by the Crown. Such stock may be rejected by the company if stock is slated for FMA planting areas.

One significant problem that has surfaced, and is now being addressed at annual renewal, is the disparity between stock standards established under our growing agreements and stock standards required by the FMAs. As the middleman in the process of supplying container stock, the Ministry is in a difficult situation if these contracts do not mesh.

The above considerations are now being looked at and may be incorporated in our future growing agreements.

In conclusion, the implementation of the private container stock production programme has been a complex and difficult process, both from a growing and a contracting standpoint. We have just completed one full growing cycle with some of our private growers and we have limited data available at this point in time on which to objectively evaluate the programme. Strictly in terms of creating the production capacity for container stock, we are well within our targets. Whether we are successful in generating the capability to produce top quality stock remains to be seen.

XIV

ACCLIMATIZING AND OVERWINTERING SPRUCE CONTAINER STOCK

S.J. Colombo

Winter damage to spruce container stock is a serious problem in Ontario. Between 35% and 50% of most overwintered spruce container seedlings have suffered some injury since monitoring of damage began in the winter of 1980/81 (Colombo, 1982). Overwintered spruce container seedlings will soon be one of the most common stock types produced in Ontario. Projections are for about 50 million seedlings to be produced annually by 1988 — approximately 25% of all seedlings produced for reforestation. Given the increasing prominence of overwintered spruce container stock, the impact of winter damage on stock quality will be great unless overwintering methods which reduce or eliminate winter injury are developed.

Current Hardening Regime

The accepted method for hardening traditionally involves two steps: the level of nitrogen fertilizer is reduced, and the greenhouse is cooled by ventilation (Carlson, 1979; Tinus and McDonald, 1978). This hardening regime normally begins in August, between one and three weeks before seedlings are to be moved outside. Seedlings are moved outside any time from mid-August to late September. No monitoring for the readiness of the seedlings to be exposed to frost is performed before moving the stock outside. This system has proved inadequate, because it disregards the natural time requirement necessary for seedlings to change from active height growth to budset and dormancy, with their associated high levels of frost hardiness. Presently, seedlings are moved outside only shortly after buds have been initiated (Colombo, 1982; Colombo et al., 1982). Our tests indicate that a minimum of six weeks is required after bud initiation before seedlings are resistant to moderately heavy frost (-5°C to -8°C). Seedlings moved outside before this time are susceptible to winter injury. In addition, seedlings exposed to damaging frosts before full hardening is achieved are unable to complete some of the other aspects of the hardening process, and so will be susceptible to damage throughout the entire winter.

Extended Greenhouse Culture

Extended greenhouse culture is a new hardening regime intended to allow seedlings to harden-off inside a greenhouse protected from freezing temperatures, until it can be shown by testing that the hardening process is complete. Only then are seedlings placed outside for overwintering.

Three aspects of the hardening process are considered vital for determining readiness for overwintering: frost hardiness, bud development, and needle maturation. Of these, frost hardiness and bud development are now being used operationally to monitor the state of winter hardiness in spruce container seedlings.

Monitoring Procedures

Frost hardiness is being monitored operationally by the Ministry of Natural Resources using the diffusate electroconductivity method (van den Driessche, 1976). Using facilities located at the Swastika Forest Station, frost hardiness is determined by measuring the amount of damage induced in a controlled freezing test. Detached seedling shoot tips are placed in a programmable freezer in which the temperature is slowly dropped to a predetermined level, usually -10°C or -15°C. Frozen shoot tips are then immersed in distilled water. The electrical conductivity of the water increases in proportion to the amount of damage caused by freezing, as freezing damages the cell membranes. Damaged cell membranes are unable to prevent the loss of cell electrolytes into the bathing solution. When only low conductivity values result from freezing, the seedlings are considered to be sufficiently frost-hardy to be moved outside. Methods for operational frost-hardiness monitoring are described in a manual now being prepared for publication.

The second aspect of the hardening process, which is being monitored, is bud development. Buds contained the preformed needle primordia from which most of the second season's height growth will result. Large increases in frost hardiness do not occur until bud development is 90% or more complete. Bud development is monitored by dissecting buds and observing, under a microscope, the number of needle primordia present (Pollard, 1973). The use of extended greenhouse culture, in addition to protecting seedlings from frost, allows buds to develop under warm conditions inside the greenhouse. In 1980/81 buds of black spruce container seedling produced under current hardening regimes contained, on average, 75 to 100 needle primordia. With extended greenhouse culture, buds can contain more than 250 needle primordia (Colombo, 1982). The upper limit of bud development has not yet been determined, but indications are that large seedlings may form buds that have 350 to 400 or more needle primordia. Buds containing large numbers of needle primordia will possess increased second-year height potential, a factor which is often vital to the establishment of container stock plantations due to the small initial seedling size.

Needle maturation is the third aspect of the hardening process and is considered to be a key to successful overwintering of spruce container stock. The greatest damage in overwintering often comes as a result of seedling dessication during the winter, if there a thaw which reduces the snowcover, exposing the seedling shoots while the roots remain frozen. Under these conditions, improperly hardened spruce seedlings lose water from the shoot, resulting in dessication damage. Extended greenhouse seedlings are resistant to dessication damage. The nature of dessication resistance is not yet fully understood, but it is assumed to be attributable to more complete needle maturation, which occurs when hardening takes place in a warm greenhouse. More work on this aspect of winter hardiness development is needed before extended greenhouse culture can be used operationally with full confidence.

In conclusion, the hardening of spruce container seedlings for overwintering is perhaps the single most important factor affecting container stock quality. Proper hardening with extended greenhouse culture should result in seedlings with good second-year growth potential due to well-developed buds, and which are resistant to both fall frosts and winter dessication.

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XV

A SYNOPSIS OF THE ACCELERATED TRANSPLANT PRODUCT (ATP) PROGRAMME AT THE SWASTIKA FOREST STATION

Randy Morrison

What Are Accelerated Transplants?

At Swastika, this term refers to the production of black spruce seedlings in a controlled greenhouse environment and when transplanted to a semi-controlled bare-root nursery environment. This type of stock is signified as 3G+1 1/2, the 3G representing three months in the greenhouse, and the 1 1/2 representing one and one-half years in bare-root nursery beds.

How Do You Produce These Products?

The crop is started in April inside a climate-controlled greenhouse. The objective is to produce 300 000 transplantable seedlings three months later. The objectives for the growth parameters at transplant time are as follows: seedling height, 12 cm; root collar diameter, 1.1 mm; total dry weight, 200 mg.

In early July this conditioned stock is transplanted to the bare-root nursery where it will remain for another year and a half.

Why Produce Accelerated Transplants?

- Accelerated transplants have a crop rotation of two years (3G + 1 1/2) as compared to the conventional three-year bare-root stock (1 1/2 + 1 1/2).
- There is a 68% reduction in the amount of seed needed because of the greenhouse environment.
- There is increased dependability in meeting shipment targets. (Overwinter losses in 1+0 Sb bare-root seedbeds, for example, was 33% in April, 1981, due to abnormal cold temperatures and no snow cover.)
- There is a reduction of cull to 5% at time of lift for transplant, compared to 30% to 50% nursery-grown.

- Automation is more readily achieved in a greenhouse environment, especially in handling and transplanting.
- The crop tends to be more uniform due to a controlled greenhouse environment.

What Potential Does the ATP Programme Have?

The accelerated transplant product (ATP) programme at the Swastika nursery is in a period of development. The expertise gained through this program now will enable nursery staff to produce the increased numbers needed when the demand for ATP increases and the programme is expanded. In the 1983 growing year, 3.7 million ATP were transplanted, with a ship target of 2.99 million for 1985. Of this, one million were contracted out to a private greenhouse grower and then transplanted by the nursery staff at Swastika.

The major emphasis in 1981 and 1982 was to compare several container systems over various sowing and transplanting times. In 1981, the paperpot, peat cubes, and bare-root systems were tested; in 1982 Spencer-Lemaires and "cigarettes" were added. Generally, early results indicate that any container is better than the bare-root system, and transplanting should be done in July. More work is needed to determine the best timing for sowing and transplanting.

Other trials include testing of growing media -- white spruce and pregermination in 1981 along with conditioning trial (white and black spruce); and fertilizer trial and growing medium in 1982. A cost analysis has also been completed by the consultants, Ernst and Whinney. Results indicate that accelerated transplants are more expensive, but that some development will substantially reduce the production costs. Major cost areas have been identified as container, greenhouse construction, and tending in the greenhouse. These costs vary among the ATP systems, mainly due to different densities.

It is hoped that ATP will replace conventional 1 1/2 + 1 1/2 as soon as possible for black spruce.

XVI

THE MULTIPOT SYSTEM

Robert A. Klapprat

Although containerized tree seedlings have been grown in Ontario for several years, many shortcomings have been experienced with certain container types. In an attempt to avoid problems associated with certain systems, the advantages of each were carefully reviewed with respect to logistic, economic, and biological suitability. From this review, the rigid container with multiple cavities (multipot) appears to be most suited to our needs.

The rigid container used here is identified as the CAN-AM #1. It has 67 cavities, each with a volume of 57 cc or 3.5 cu in. The yellow colour was chosen to make them more visible, thus increasing the likelihood of their return for reuse.

The multipot, however, is only one component of the system. To facilitate handling, growing frames were designed and constructed to accommodate 30 multipots which contain approximately 2000 trees. Multipots are placed on the growing frames as they come off the seeding line. When a frame is full, another is stacked on top of it, to about four or five units in height. The stack is then carried off to the greenhouse and positioned with a forklift.

The legs on the growing frames support the multipots about 15 cm above the greenhouse floor, to avoid the low temperatures at floor level during winter production. This elevation also prevents elongating roots from penetrating the floor material, and allows air pruning of roots that protrude from the container. After the trees are grown, the forklift can again be used to stack the growing frames and move them from the greenhouse, into and out of acclimatization holding areas, and in preparation for shipment. Shipment is facilitated by a custom-built trailer which is equipped with a movable overhead winch system that can place five stacks of six growing frames in the trailer and unload them at the holding or planting site.

XVII

THE ATMOSPHERIC DEMAND FOR EVAPOTRANSPIRATION: A RELIABLE MEANS FOR IRRIGATION RATE CALCULATION

C.S. Papadopol

During its life cycle in the nursery, a crop is subjected to complex and rapidly changing influences as part of the soil-plant-atmosphere continuum (SPAC). Many of these influences can create stresses, resulting mainly from radiation, temperature, and moisture. In most cases the deficiencies and/or stresses experienced by crops decrease growth and biomass accumulation in proportion to the intensity of the stress, which in extreme cases can be lethal.

It is generally recognized that the ability of trees to cope with various adversities, particularly those related to climate, is stadial, and that the most critical stage occurs early, when the plantlets and seedlings face the aerial and root environment as isolated individuals unable, at this stage, to fully exploit the potential soil reservoir. During this phase the greatest danger comes from heat and moisture stress. In the nurseries it is of utmost importance to gain a thorough understanding of physiological influences acting on crops of different ecological requirements, and to find means to alleviate these stresses. Traditional nursery management techniques, including shading and irrigation based on soil-moisture condition, are now fully described (Armson and Sadreika, 1979; Bunting and Timmer, 1981) and represent current practice for raising superior quality stock.

The aim of this paper is to present the concept of the atmospheric demand for evapotranspiration and its use in estimating irrigation water requirement, and for operation of water supply systems in the tree nurseries.

The Concept of Evapotranspiration

In the decades following the Second World War, an enormous international scientific effort has been made on irrigation as a cultural technique by which crop yields can be significantly increased and become more secure. This has led to important theoretical progress relating to water evaporation from soil and transpiration from vegetation to the controlling atmospheric and plant factors. The publication of Penman's theory on evaporation from field crops in 1948 was a cornerstone for the water supply activity which, from that time on, could have risen from dilatant watering to scientific control of water availability to crops.

Penman's breakthrough was based on a combination of the equation describing the energy balance at the earth's surface with the so-called aerodynamic equation relating the evaporation from a water surface to the gradient of vapor pressure of the air. In this way, the potential rate of evaporation could be calculated from standard meteorological measurements and physical constants. Potential evapotranspiration (ETp) — subsequently defined as the water consumption of a short dense grass which is never deficient of water or, more exactly, the rate at which water, if available, would be removed from the soil and plant surface expressed as a latent heat transfer per unit area — was to become the basis for contemporary estimates of crop water requirements. Prestigious works on irrigation (Dorenboos and Pruitt, 1977; Jensen, 1981; Finkel, 1982) now recommend Penman's approach for the calculation of water requirements of crops and particularly for irrigation rate prediction, whenever suitable climatic information is available.

Extended comparative studies about the relation between ETp and actual evapotranspiration of crops (ETa), as measured with lysimetric installations, have also emphasized the influences of plant type, crop structure, foliage colour, phenology, etc., on the real water consumption of a certain crop. To adjust the ETp to the specific requirements of a crop at a certain stage of its development, the agronomists carried out detailed investigations and calculated the so-called crop coefficients, which are crop- and phase-specific and incorporate the effects of the growth stage, crop growth density, and other cultural factors. Unfortunately, similar studies have not yet been made for tree crops, so that such coefficients for nursery crops or forest stands do not exist to date.

The need to integrate the existing knowledge about the evapotranspiration process with meteorological data, irrigation, and yield has led to several computer models such as CORNGRO for maize (Kundu et al., 1982) and WATER for twelve agricultural crops (Burt et al., 1981), which, among other things, calculate the ETa using the Penman approach. A more sophisticated model, useful particularly in research, was produced by Hillel (1977).

Problems relating to the modelling of water consumption of forestry crops with different structures represent an important research topic in ecophysiological studies in the last two decades. Several of these models were compared in regard to their performance and sensitivity to environmental changes, and the results showed some outstanding qualities (Haldin, 1979). While conceptually based on the Penman approach, some of the models attempt to define and quantify parameters related to the structure of canopy, with the aim of achieving a fine-tuning to a certain forest type. Naturally, the sensitivity of these models depends on the number of monitored atmospheric variables and frequency of measurements. The input for these models is usually derived from automated meteorologic equipment, which is scanned at regular intervals, sometimes even every ten minutes. The essential parameters for these models are: dry and wet temperature values, net solar radiation, and wind speed.

However, use of this impressive scientific achievement in forestry, and particularly in projects dealing with intensive culture and nursery problems, has lagged considerably behind the available progress in technology and knowledge.

One of the greatest potential applications of these advances is in the irrigation management of the nurseries and seed orchards. Together with the energy farming, these are the most intensive crop systems applied in silviculture. Converting the existing knowledge in micrometeorology and evapotranspiration into an operational decision-making process is a challenging job, which can be accomplished at the current stage of technology (monitoring, data processing, and control) provided consideration is given to a number of conditions specific only to forest nursery crops.

Constraints Specific to Nursery Irrigation

As compared with an established stand, a nursery crop is much more vulnerable to stress influences, mainly as a result of two traits: (i) the roots only explore a very limited soil volume, and (ii) the canopy does not cover the soil completely. As a result, any strong atmospheric influence such as intense radiation or a dry wind can draw the water from the upper layer of soil up to or even beyond the wilting point. Since the roots of the plantlets depend only on a limited stratum of soil, which is the first to be depleted of water, the consequences can be very serious. Prevention of such a condition on sandy soils (easily drained soils) can only be achieved by shortening the interval between irrigations.

Another important constraint refers to the availability of nutrients. In the nurseries located on sandy soils in areas with a positive balance between precipitation and evapotranspiration, there is an almost permanent downward flow of percolating water, which has the tendency to leach any nutrient solute to the groundwater. This flow is stopped only during the summer months, for the periods when the evapotranspiration exceeds the incoming rainfall. As a result, there is only a limited period which is climatically controlled and subject to annual variation from one year to another in which the fertilizers can be applied; during the rest of the year, the same are being leached into the groundwater. But leaching of this valuable soil solute can occur also as a result of only slightly excessive irrigation, which will replace the solute with water. To escape from this dilemma, one should only irrigate with rates which will not trigger the gravitational move of the water, and only where a certain part of the water soil reservoir has been depleted. As a consequence, a correct strategy to match this objective would be:

(a) to calculate daily, in the summer period, the atmospheric demand for evapotranspiration as exerted over the soil and crops;

(b) to irrigate with variable rates matching the demand for evapotranspiration;

(c) to stop irrigation where rain is forecasted within the next 24 hours, in order to avoid the overflow of the soil reservoir;

(d) to closely monitor a soil water budget for the smallest uniform irrigation unit (a line of sprinklers, a crop, or a compartment);

(e) to continuously monitor the soil water condition and to know daily what the average soil water content was as compared, for instance, with field capacity (FC) or another meaningful threshold.

The Penman Combination Formula — A Short Interpretation

As mentioned previously, the Penman approach to atmospheric demand for evapotranspiration estimation represents a convenient way to integrate all short-term variations of atmospheric parameters relative to the evaporation process. Since the ETp is controlled by the atmospheric conditions, it becomes obvious that, as long as the water is not in short supply, ETa from different types of vegetation should be largely similar if they are subject to similar weather conditions. However, there are two factors which can make the ETa of various crops differ, namely: the albedo (the proportion of reflected radiation of the total incoming radiation) and the aerodynamical roughness of the crops. The reader interested in details about these topics is referred to mathematical developments used by Brock (1981), Graser and Van Bavel (1982), Haldin (1970), Hillel (1977), and Van Bavel (1966).

Since Penman originally published his theory in 1948, it was slightly modified by different authors who generally altered the mathematical functions for radiation, wind, and water vapour pressure. Several approaches are currently in use, namely: Dorenboos and Pruitt (1977), Jensen (1981) and Thompson (1982). The following is a short presentation of the form presented by Jensen (1981).

The Penman combination equation for the potential evapotranspiration expressed in cal/cm^2.day is:

$$\mathrm{ETp} = \frac{D}{D+Pc}(Rn+G) + \frac{Pc}{D+Pc}\,15.36\ \mathrm{WF}\ (ea-ed) \qquad (1)$$

where: D is the slope of the vapour pressure - temperature curve in mb/°C; Pc is the psychometric constant in mb/°C; Rn is net radiation cal/cm^2.day; G is the soil heat flux at the surface in cal/cm^2.day; WF is the wind function, dimensionless; (ea–ed) is mean daily vapour pressure deficit in mb; and 15.36

is a constant of proportionality in cal/cm^2.day.mb.

Other expressions for some of the terms are:

$$D = 2.(0.00738T + 0.8072)^7 - 0.00116 \quad (2)$$

$$Pc = \frac{0.386P}{L} \quad (3)$$

$$P = 1013 - 0.1055E \quad (4)$$

$$L = 595 - 0.51T \quad (5)$$

$$es = 33.8639 \left[(0.00738T + 0.8072)^8 - 0.000019\,(1.8T+48) + 0.001316)\right] \quad (6)$$

where: T is mean daily temperature in °C; P is the barometric pressure in mb; L is the latent heat of vaporization in cal/g; and E is elevation in m.

The description of the radiation and wind functions would require more space and would be beyond the scope of this paper. For these topics, the reader is referred to recent works published by the American Society of Agricultural Engineers (ASAE).

Although presented above in a form suitable for a unique daily computation, using average temperature daily sums for radiation fluxes and the total wind run in 24 hours, with suitable modifications, the same approach can be taken for shorter intervals. The advantage of using shorter intervals than a day (provided meteorological information is available) rests with a more exact consideration of the short-term atmospheric events which occur during a day, such as intermittent clouds, wind bursts, or dry air invasion, which may get obscured in daily averages. This fact becomes more obvious if we consider the power of temperature terms in equations (2) and (6), and also the even more complex expressions for radiation and wind. Consequently, the calculation of ETp for short intervals (i.e. 15 or 60 minutes), using the atmospheric parameters for that particular time of the day followed by the integration of the "scanned" results into a daily total, would likely produce results of greater precision than those calculated using daily average values.

A Computer Model for the ETp: Penman

As part of a more comprehensive research project, aiming at the integration of the existing knowledge related to water and nutrient cycling into an operational system, a computer model was developed for the water cycle part of that system. The model has been written using the extended capabilities of the language BUSINESS BASIC available on an Apple III computer with 256K memory.

The sequence of operations around which the model was built runs, in short, as follows:

(a) the sensors of an automatic weather station are scanned every ten minutes and data for temperature (dry and wet), radiation, wind run, and air humidity is stored on a tape;

(b) once a day the tape with the 24-hour information is read into the computer, which calculates the ETp and updates a file with hourly atmospheric and evapotranspiration data;

(c) calculations are performed on the input data by three subroutines with different time intervals: 10 minutes, 60 minutes, and 24 hours, allowing finally for a comparison of the results.

If operated as a dedicated equipment for daily calculation, a main microcomputer can be operated from a remote location sending the data over a telephone line and waiting for the answer. A convenient terminal for this use could be the portable computer "Model 100" produced by Radio Shack. The unit has a built-in mode to facilitate telecommunication and a small screen on which the results can be displayed.

To illustrate what we give and lose in the precision of ETp calculation as a result of the time interval of data calculation, in Table XVII-1 the atmospheric parameters and ETp values calculated from data taken at various intervals on some characteristic days are compared. These data show that for days with fairly similar average temperature and net radiation, the ETp values are dependent on the wind influence. Calculations of ETp made from hourly scans are 0.1 to 0.2 mm lower than those made when the sensors were scanned at ten-minute intervals. When daily averages for temperature and daily totals for net radiation are used as the input data, the figure of ETp is reduced by 0.5 to 0.7 mm; this reduction is proportional to the total daily wind run.

A Simplified Approach: Blaney-Criddle

The Penman model requires that the atmospheric data be collected according to standardized procedures. This, in turn, requires application of specialized equipment costing approximately $10 000. The investment, however, is fully justified considering the irrigation efficiency and productivity of a nursery. Where such equipment is not initially available, the potential evapotranspiration can still be calculated within satisfactory limits of precision using considerably fewer input data.

The Blaney-Criddle method, due to its simplicity and the use of readily available data, is probably the best known and most widely applied formula for the calculation of ETp. In its latest version, presented by Dorenboos and Pruitt (1977) and Finkel (1982), the potential evaporation of a reference crop is calculated in the following formula:

$$ETp = a + b\,p\,(0.46T + 8) \qquad (7)$$

where: ETp is the potential evapotranspiration in mm/day; p is the percentage of daylight hours of a day; T is the average air temperature; and a and b are coefficients depending on sunshine, wind, and air humidity.

As can be seen, it actually requires only two factors: the latitude (for p) and the mean daily temperature. The a and b coefficients represent correction factors taken from tables to which the entries are qualitative, the data being represented as classes such as low, medium and high for the sunshine, wind and air humidity. The values of p, a, and b are given in tables published in the above-cited works.

Examining the Blaney-Criddle formula, one can note that it is, in fact, merely an empirical simplification of the Penman method, since the atmospheric factors considered are the same. That explains, perhaps, its unsurpassed application and success all over the world.

To make it available to nurserymen in Ontario and to avoid the need for daily calculations, another computer programme was written and is operational at Maple. The programme produced a table, presented here as Table XVII-2, using as entries only the name of the place and its latitude. Since the daylength changes slowly during the season, modifying the value of p, the table has to be produced only at weekly intervals. Once this is done, the only quantitative entry in the table is the average temperature; the rest of the entries require only qualitative evaluation. For example, in Table XVII-2, for a day with an average temperature of 26, high sunshine, low air humidity, and medium wind, the ETp will be equal to 9.76 mm.

From ETp to Irrigation Rate

Basically, all formulae for ETp produce a close approximation of the evaporation potential of water into the atmosphere under specific conditions. However, at this point a question arises: what irrigation rates should be applied to crops of varying characteristics to correct the calculated moisture losses? A discussion on this matter, intensely researched by our fellow agronomists, can be very long — in fact, almost endless.

Several circumstances complicate the conversion of the ETp to the irrigation rate. Perhaps the main factors are the incomplete row cover of the crops, the phenological development of plants, and the losses of sprinkling water (from the vegetation, or directly into the air) before it can reach the soil.

The influence of the crops with incomplete row cover on the heat balance, and consequently on evapotranspiration, is most complex as it involves (among other things) the differing albedo values for the strips of crops and open soil. The interested reader is referred to the works of Ritchie (1972), Tanner and Jury (1976), and Showcroft and Gardner (1983).

Once crops have reached the stage of complete canopy closure, the water consumption of short crops comes very close to the ETp figure. From that time on, the direct evaporation from soil decreases sharply and the transpiration of the crop can be related with the ETp through the leaf area index similar to the one obtained by Ritchie and Burnett (cited by Barfield and Gerber, 1979):

$$Tc = ETp\ (-0.21 + 0.70\ LAI\ 1/2) \qquad (8)$$

where: Tc is transpiration of crop in mm, and LAI is the leaf area index, dimensionless.

A systematic study of such a relation applied to several nursery crops, combined with observations about leaf area growth during the season, would lead to an expression of the crop coefficient depending on the stage of crop development similar to the one obtained by Idike (cited by Barfield and Gerber, 1979):

$$Kc = 0.152 + 0.0164DAE - 0.00012\ DAE^2 \qquad (9)$$

where: Kc is the crop coefficient at a certain point in time, and DAE represents the number of days after the emergence of crop.

Obtaining a relation of this type for the main nursery crops of different ages should be an objective of immediate priority in research.

Another factor which modifies the water quantity which really gets into the soil is the direct evaporation of the sprinkled water. Here, several factors such as air humidity and air circulation during the sprinkling are of utmost importance, particularly where the degree of dissipation of the water droplets is high as a result of sprinkler construction and high operation pressure. This can lead to direct evaporation which may be as high as 40% of the total flow (Jensen, 1981). Also, the quantity of water which evaporates directly from the wet foliage is sizable, as pointed out by Haldin (1979) and Batchelor and Roberts (1983). Although these quantities of water produce temporary cooling effects, they do not reach the soil water reservoir and cannot be manipulated by the seedlings.

An Operational Irrigation System Based on the Atmospheric Demand for Evapotranspiration

At this stage of knowledge and available technology, the time has come for a radical improvement of the nursery irrigation system. The Ontario nurseries, together with other users such as the tree seed orchards, can all become part of one irrigation network based on a central computer having the evapotranspiration model permanently accessible. Meteorological equipment and terminals located at each user can accomplish the transfer of the data to the model and receive the results. Several almost similar systems of data acquisition, processing, and control of parameters are already in use in several agricultural applications (Mitchell, 1983).

An even more advanced step would lead to the complete automation of irrigation, which, of course, will require some adaptations and changes of the equipment. Studies on automation of irrigation systems are well under way in several centres in North America, with very promising achievements (Jensen, 1981; Moutonnet et al., 1981).

An important advantage of a more complex irrigation system comes from the use of the computer. The advent of cheap microcomputers with high memory capacity, but usually limited or slow data-entry devices, makes them eminently suitable to operate as data acquisition systems which can be programmed to repeatedly perform intricate calculations and subsequently control the functioning of some additional devices according to the results; in fact, maintaining the optimal levels of the key parameters for operational irrigation. The microcomputer will have, in the future, an increasingly important role in the control of growth factors such as water and fertilizer supply, thus shifting human involvement from operation to control and supervision (Harrington and Heerman, 1981; Moser et al., 1983).

Future Research and Developments

No matter how attractive an automated irrigation system is from the operational standpoint, it is only as good as the laws which govern it. From this point of view, research should be intensified with aims of achieving several priority objectives.

A better understanding and practical application of the theory of infiltration of water to soils (Hillel, 1977; Ghosh, 1980) would be particularly important for maintaining soil moisture levels in sandy soils. That should develop, also through computer operation, into another layer of a large model which will monitor and update, at short intervals, the water balance of different crops. Having local information on a permanent file, and fed with data about actual water-soil condition (coming from tensiometers or neutron probes), the computer can present, at the end of the season, the variations and perhaps stresses to which the crop was subjected. This can then suggest changes in the frequenty and/or amount of irrigation.

There is also an urgent need for a quick evaluation of crop-specific aerial and underground parameters for correcting the potential evapotranspiration. That would involve studies on the seasonal variation of leaf area and root depth, at least for the main forestry crops.

Such information can be immediately adapted from the enormous amount of data which has been gathered and developed by agronomists. However, for a highly efficient use of the water and nutrients, such information has to be developed also for nursery crops.

It is the view of the author that, while an irrigation scheduling system based only on soil or atmospheric data is biased, a more sound system has to integrate climatic, crop, and soil data, and use the latest achievements of the micrometeorology and soil science. At the same time, the repetitive data collections and processing operations of data should be assigned to microcomputers.

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Table XVII-1: The ETp values
calculated for various time intervals

Atmospheric parameters			Daily sum of ETp (in mm) calculated from time intervals of:		
Average Temperature (celsius)	Total Net Radiation (langley)	Daily Wind Run (km/day)	10 Minutes	1 Hour	24 Hours
22.88	582	94	6.24	6.09	5.73
23.29	580	98	6.33	6.17	5.78
23.18	510	180	6.33	6.15	5.79
24.55	520	212	6.74	6.55	6.22
24.19	525	268	7.19	6.99	6.61
23.62	535	300	7.51	6.30	6.81

Table XVII-2: Potential Evapotranspiration for Maple for the period July 24-30 (mm/day, latitude 44 degrees and 0 minutes)

Wind	Potential Evapotranspiration for Temperatures (in celsius)									
	16	18	20	22	24	26	28	30	32	34
Sunshine: low		Air humidity: low								
low	3.86	4.22	4.57	4.92	5.27	5.62	5.97	6.32	6.67	7.03
medium	4.73	5.12	5.51	5.90	6.29	6.68	7.07	7.46	7.86	8.25
high	5.54	5.97	6.39	6.82	7.25	7.68	8.11	8.53	8.96	9.39
		Air humidity: medium								
low	3.35	3.68	4.00	4.32	4.64	4.96	5.28	5.60	5.92	6.24
medium	4.01	4.37	4.72	5.07	5.42	5.77	6.12	6.47	6.82	7.18
high	4.67	5.06	5.44	5.82	6.20	6.58	6.97	7.35	7.73	8.11
		Air humidity: high								
low	2.63	2.87	3.12	3.36	3.61	3.85	4.10	4.34	4.58	4.83
medium	2.94	3.21	3.48	3.74	4.01	4.28	4.55	4.82	5.09	5.36
high	3.35	3.65	3.95	4.25	4.54	4.84	5.14	5.44	5.74	6.04
Sunshine: medium		Air humidity: low								
low	4.58	5.00	5.41	5.82	6.23	6.65	7.06	7.47	7.88	8.30
medium	5.85	6.33	6.80	7.27	7.75	8.22	8.69	9.17	9.64	10.12
high	7.02	7.55	8.08	8.61	9.14	9.66	10.19	10.72	11.25	11.78
		Air humidity: medium								
low	3.92	4.29	4.65	5.02	5.39	5.75	6.12	6.49	6.85	7.22
medium	4.89	5.31	5.73	6.15	6.57	6.99	7.42	7.84	8.26	8.68
high	5.65	6.12	6.58	7.04	7.51	7.97	8.44	8.90	9.37	9.83
		Air humidity: high								
low	3.15	3.44	3.74	4.04	4.33	4.63	4.92	5.22	5.52	5.81
medium	3.66	3.98	4.30	4.63	4.95	5.27	5.60	5.92	6.25	6.57
high	4.22	4.57	4.92	5.28	5.63	5.99	6.34	6.70	7.05	7.40
Sunshine: high		Air humidity: low								
low	5.30	5.78	6.25	6.72	7.20	7.67	8.14	8.62	9.09	9.57
medium	6.98	7.54	8.09	8.65	9.20	9.76	10.32	10.87	11.43	11.98
high	8.51	9.13	9.76	10.39	11.02	11.65	12.28	12.91	13.54	14.17
		Air humidity: medium								
low	4.59	5.00	5.42	5.84	6.26	6.68	7.10	7.52	7.93	8.35
medium	5.71	6.20	6.69	7.19	7.68	8.17	8.66	9.15	9.64	10.14
high	6.73	7.29	7.84	8.40	8.95	9.51	10.07	10.62	11.18	11.73
		Air humidity: high								
low	3.66	4.01	4.36	4.71	5.06	5.40	5.75	6.10	6.45	6.80
medium	4.27	4.64	5.02	5.39	5.76	6.13	6.51	6.88	7.25	7.63
high	4.98	5.38	5.78	6.18	6.58	6.98	7.38	7.78	8.18	8.58

XVIII

THE NEW IRRIGATION SYSTEM

D.J. MacNaughtan

Many nurseries in the province now have new, updated irrigation systems so I won't dwell, at this time, on the merits of upgraded irrigation capacity. What I would like to share with you are three new concepts in nursery irrigation systems. The first of these is the passing on to the private sector the design and management of an irrigation system construction project.

When the Ministry of Government Services (MGS) first presented the irrigation system project estimates for the G. Howard Ferguson Forest Station, they were an astonishing $4.5 million. The Regional Director, realizing we had no funds for a project of this size, instructed the Regional Engineer to solicit a proposal from a private engineering firm. With some modifications that I will discuss later, this firm came in with a project estimate of $1.8 million — a saving of over $2.5 million.

Even though MGS subsequently gave us an alternative estimate of similar value incorporating some of the cost-saving changes made by the engineering firm, the decision was made to proceed with the Gore & Storrie proposal, making this the first nursery irrigation system in Ontario designed by the private sector.

There were two main differences between the MGS and the G&S systems which resulted in the large cost savings. The first was the burial of the pipe to a depth of only three feet; the second was the use of Dupont's butt-fused polyethylene sclair pipe.

At other nurseries the underground water systems are buried six feet to minimize frost damage. However, because of the type of pipe used which is less prone to damage, the shallow burial is said to be sufficient. Shallow burial also eliminated one major problem associated with this nursery: quicksand.

Butt-fusing of the pipe was done above-ground before burial, and no thrust blocks were used because little or no damage to the pipe is caused by stretching or freezing.

Although there is still some work to be done to complete the project, the system is functional and has been in use for all of this season. It is also worthy of note that the project came in under budget and we were able to complete the job for $1.8 million. This included $168 000 of aluminum surface pipe needed to maximize the efficiency of the system.

Some of the costs and technical details of the system are:

Underground pipelines	$844 000
Pumping station	590 000
Engineering	210 000
Surface pipe	168 000

Pumping capacity	210 l/s or 2490 USGPM
Irrigating capacity	5 compartments (plus)
Kilometres of pipe	11
Type of pumps	3 Fairbanks Morse vertical turbine

XIX

TREE IMPROVEMENT IN THE EASTERN REGION

Ken Eng

The Ontario Ministry of Natural Resources is commited to expanding its efforts in the field of tree improvement. Recent policy statements establish initial direction and objectives for tree improvement programmes. Additionally, the responsibilities of the various offices involved in the coordination and implementation of these programmes are outlined.

This paper will briefly highlight the direction and current achievements of the Eastern Region's tree improvement programme.

In keeping with the provincial strategy of regional programme coordination, Mr. Gerry Anderson was recently appointed to the position of Regional Tree Improvement Technician. Mr. Anderson is responsible for coordinating the tree seed collection and tree improvement programmes for the Region. He is based in the Kemptville nursery, which has been designated as the regional facility responsible for tree improvement.

One objective of the provincial strategy is "to produce all planting stock of our major regeneration species with controlled collections of source-identified seed or vegetative propagules by 1990." The Eastern Region has concentrated a large proportion of its efforts in achieving this objective. Regional guidelines, based on modifications of provincial guidelines, were developed for the establishment and management of various categories of controlled collection areas. These guidelines are outlined in Table XIX-1.

Based on the short-term projected seed requirements, establishment targets for seed production areas (SPAs) and seed collection areas (SCAs) were developed for the major regeneration species (see Table XIX-2). These figures will be adjusted, in time, as more accurate data become available on the productivity of controlled collection areas and as long-range projected seed requirements are identified. Establishment targets were then apportioned among the five Districts in the Region and implementation schedules drawn up. Schedules cover a five-year establishment period which ends in 1986. This leaves a three-year buffer period during which adjustments can be made, in order to meet the 1990 target date of the provincial strategy. Table XIX-3 outlines the SPA implementation schedule by MNR District and includes all species. A similar schedule exists for SCAs.

The seed orchard program in the Eastern Region is proceeding at a much slower rate than the establishment of controlled collection areas. This is due to the Region's desire to obtain a parcel of land close to the nursery on which seed orchards of all major regeneration species can be consolidated for ease of management as well as proximity to equipment and manpower. One seed orchard has been established in the Region which is of unique design and the only one of its type in the province — a hybrid larch orchard. The orchard contains grafted stock of various clones of European and Japanese larch. The material is arranged in a repeating pattern of three rows of Japanese larch followed by one row of European. The European larch within a row are normally of the same clone, whereas the surrounding Japanese larch are a mixture of various clones. It is anticipated that hybrid larch seed will be collected off the European larch, while a mixture of pure Japanese larch and the reciprocal hybrid larch will be collected off the Japanese larch. Material for this orchard was provided by the Petawawa National Forestry Institute of the Canadian Forestry Service.

The Region is a participant in the southern Ontario white spruce gene pool preservation programme. This programme was initiated several years ago by the Forest Resources Branch, Toronto, in cooperation with research staff from the Ontario Tree Improvement and Forest Biomass Institute at Maple. Ten tentative geographical groups have been delineated, five of which are represented in the Eastern Region. A series of clonal archives are being established throughout the south, one of which will be set up at the Kemptville nursery. The archives will eventually contain material from all ten groups, and it is anticipated that some breeding work will be done. Seed derived from this programme will be incorporated into the regeneration programmes of the southern regions.

In conclusion, the Eastern Region's tree improvement programme is a low-intensity, basic, but practical approach, which satisfies the current and immediate objective of a sustained source of identified seed. Strategies are being developed for more intensive programmes. The implementation of such strategies depends on future support in terms of commitment, funding, and manpower.

Having a permanent regional staff member to work solely on tree seed and tree improvement has contributed to the Region's success in these programmes, as well as the commitment and cooperation of field staff.

The hybrid larch seed orchard and the white spruce gene pool archive are excellent examples of incorporating research results into management programmes. These programmes also demonstrate what can be achieved when cooperation, instead of conflict, is exercised.

Table XIX-1: Tree improvement programme in the Eastern Region

CATEGORY	GPR	SCA	SPA	SOR
Function	Gene Pool Conservation	Interim Supply of Source Identified Seed	Genetically Improved Seed	Genetically Superior Seed
Origin	Average Stands	Above-average Stands	Above-average Stands	Plus Trees
Method of Seed Collection	Non-destructive	Destructive or Non-destructive	Non-destructive	Non-destructive
Expected Genetical Gain	Nil	Slight	3-5%	8-15%
Land Ownership	Other Patent Crown or Agr. For.	Other Patent Crown or Agr. For.	Crown or Agr. For.	Crown
Management: This Rotation	Regen. material on Crown or Agr. For. land Regen. on site	Regen. material on Crown or Agr. For. land Normal forestry practice Regen./Rogue	Cultural Treatment Regenerate on Site	Orchard Management
Next Rotation	Maintain Gene Pool	Manage Portions of Regenerated Stands as Seed Production Areas if Required	Manage Regenerated Stands as Seed Production Areas	Establish and Manage Up-graded Seed Orchards

Table XIX-2: Establishment targets for seed collection areas and seed production areas in the Eastern Region

Species	Seed Collection Areas (ha)	Seed Production Areas (ha)	Total (ha)
White pine	100	50	150
Larch	90	45	135
Jack pine	80	40	120
Norway spruce	70	35	105
White spruce	60	30	90
Scots pine	50	25	75
Other	50	25	75
Total	500	250	750

Table XIX-3: Selection schedule seed production areas

(includes all species)

			District			
	Brockville	Cornwall	Carleton Place	Napanee	Tweed	Total
			(hectares, cumulative)			
Prior to 1982		10.2	5.3			15.5
1982	8.8	28.3	15.3			52.4
1983	19.3	28.3	24.9		18.0	90.5
1984	30.0	36.0	33.0	17.0	29.0	145.0
1985	40.0	43.0	42.0	33.0	39.0	197.0
1986	50.0	50.0	50.0	50.0	50.0	250.0

XX

SEED EXTRACTION AND DISPATCH

Brian Swaile

I would like here to present a few changes that have taken place or will be taking place in the next few months regarding seed extraction, identification, and seed dispatch.

Seed Extraction

With regard to seed extraction, we have not changed our methodology very much over the last few years. Since the quantity of container stock production orders has increased, we have added a new piece of equipment to our cleaning floor in the way of a specific gravity table. We use this machine to help us clean the seed, and we also size seed on it. It is our belief that all seed being shipped to the nurseries for container stock production should go across the gravity table, if possible. This gives us a quantity of seed of the same density (size) and should make it a lot easier for the vacuum heads, etc., to provide one to one and a half seeds per cavity. We also understand that, because we are using the larger seed, the crop in the greenhouses are of a more even height. It has also been stated that since the larger seed is being used, the greenhouse time can be shortened because the seedlings reach the required height sometimes two weeks earlier. This can be attributed to the seed having more vigour. If we use the gravity table to size a seed lot, then that particular lot is identified as such.

That is basically the only present change in extraction. Because of the crop year just experienced, we have been investigating pre-kiln treatments to try to speed up production with existing facilities. Storage problems for cones have also been looked at because if three or more species happen to have a bumper crop the same year, we have problems. This past year gave us a good test — as some of you very well know.

Seed Identification and Computerized Inventory

The next two items I would like to discuss are the new seed identification and our new computerized inventory. We have been working on the inventory for the past five to six months and it is hoped that by September it will be in place. At present we are able to provide some information, but not for every species. The new identification numbers were designed for the computer.

I brought a sample of what the computer printouts look like, and I will try to explain them so that when you are ordering seed you will have some idea of what is in storage. With the computerized inventory we hope to be able to provide an up-to-date picture of what is in storage — not something that is produced June 1st, August 1st, or January 1st and is obsolete by the time you get it because we have shipped or stored new seed. The new inventory is different in that everything is stored by seed lot. We used to store by container and only we had that information. Now with the computer printouts you can see how the seed is stored, so that you can choose a particular seed lot when requisitioning.

Direct Shipping of Hardwoods

Another item I would like to touch upon with regard to the southern nurseries is the shipping of some hardwoods directly from the Districts to the nursery. It has been proven that germination results are better. Alf can verify this with the results he had with both red and silver maple last year.

I would like to point out that the nurseries should report to Angus the quantity received in hectolitres and the number of viable seeds sown, so that we can input this information into the new inventory system.

XXI

SEED UTILIZATION: BARE-ROOT NURSERY STOCK PRODUCTION

C. F. Mansfield

A primary requirement for the regeneration of forest lands is planting stock from a seed source of proven adaptability to the planting site. The intensive timber culture that is being applied to our most productive forest lands separates and identifies specific stands on the basis of their vigour and wood or fibre production.

Seed utilization as it applies to bare-root nursery stock production encompasses all activities that promote the most efficient use of seed.

Quantity evaluations for each inventory item throughout its growing period on the nursery are absolutely essential.

For each seed lot, the nurseryman must determine the proportion of viable seeds sown that is likely to produce plantable seedlings at the time of lifting. This factor is based on both expected nursery germination and seedling survival in the beds.

1981 Seeding Ratios* (tree percentages)

	Species				
Nursery	Pw(3+0)	Pr(3+0)	Pj(2+0)	Sw(t)	Sb(t)
A	3.7:1	4.0:1	2.7:1	5.1:1	6.6:1
B	4.2:1	4.5:1		9.0:1	
C	5.0:1	3.2:1	2.7:1	12.1:1	9.1:1
D	3.2:1	2.8:1	2.9:1	4.6:1	6.3:1
E		3.5:1	3.0:1	5.2:1	7.6:1
F		2.6:1	2.1:1	7.7:1	9.3:1

* Seeding ratio refers to the number of viable seeds sown per shippable tree produced.

Annual inventories are summarized and the cumulative records are translated into composite survival factors. These factors are expressed as a percentage from viable seeds (0+0) to shippable trees. Factors are determined for each species grown and for each year of its development.

Example: White spruce for three-year transplant production

Composite survival	0+0	to ship	22%
	1+0	to ship	45%
	1 1/2 + 0	to ship	60%
	1 1/2 + 1/2	to ship	64%
	1 1/2 + 1 1/2	to ship	80%

For anyone not associated with the sowing operations and the assemblage of the information prior to seed requisitions, there are some sobering realities.

It is quite possible that a particular container of seed could have a germinative capacity of almost one hundred per cent under controlled germination tests. The actual germination under nursery field conditions may result in only fifty to sixty per cent of this seed producing 1+0 seedlings. Throughout the balance of the seedlings' development in the seedbed, the population continues to decrease. As few as five white cedar seeds may survive to become acceptable planting stock four years later.

It is now common practice to spring-sow nondormant seeds. Dormant seeds require proper pregermination treatment to be successfully spring sown. Unless seeding is carried out during the early spring, fall-sown seeds usually produce larger and better developed 1+0 seedlings. For most conifer species, the germination capacity of the seed is increased through spring seeding. Most seed is now drill sown. The amount of seed sown per unit area and the sowing density vary with the species, germination capacity, and the desired seedling density. The stock density influences the vigour and size of the seedlings and transplants produced.

Seeds are sown at densities selected to produce from 15 to 75 seedlings per square foot. Higher tree survival factors are obtained when medium-to-low sowing densities are used. Ultimately, experience determines the correct sowing density for a given species and nursery for a particular planting situation.

Most nurseries are now using seeding devices built around an Oyjord metering device. While these units are remarkably accurate when it comes to metering seed, and have made it possible to sow small quantities of seed with relative ease, the units are continually being modified.

When we consider the accuracy and reliability of the cavity filling devices that have been developed for container-grown stock, the seeding equipment used for bare-root nursery stock production is still quite primitive.

Forest productivity will be further increased by planting genetically improved seedlings which are becoming available in increasing numbers. To maximize the potential of such superior seed will require the development of precision seeding devices and refined nursery practices.

XXII

SEED UTILIZATION IN CONTAINER STOCK

J. deWitt

We face many problems when trying to plan the seeding of our greenhouses. I intend to focus on the problem of whether to single seed, double seed, or triple seed. To make a sound economic decision without just relying on our "gut feeling," what factors should we be looking at? Let's look at some of the factors individually before attempting a decision.

How much of this seed is available?

(a) If supply is limited, then we have to conserve seed; so perhaps a single sow.
(b) If it is plentiful, perhaps a multiple seeding is best.

How much is this seed worth?

(a) If it is expensive, again a single sow.
(b) If it is cheap, we can be more extravagant.

What is the germination percentage?

(a) If it is 85% and up, perhaps a single sow will suffice.
(b) As the germination drops, increase the seed per cavity.

What are the heating costs?

(a) If they are high, we need multiple seeding to keep down the cost per thousand trees produced.
(b) If low, perhaps single or double will suffice.

What are the thinning costs?

(a) If they are high, single seed.
(b) If low, multiple seed.

What are the restocking costs?

(a) If they are low, single seed.
(b) If high, multiple seed.

These are a few of the things to consider; but how do we determine which of the above factors are important in a particular case?

If we are heating, does it make more sense to single sow and risk blanks, or triple sow and incur thinning costs? Do we bring down the cost per thousand enough to justify triple seeding and paying for thinning? Maybe the thinning will push up the cost per thousand more than the blanks would.

With such a multitude of factors to consider, how can we logically determine the number of seeds per cavity to give us our lowest cost per thousand seedlings?

Will Pepper and Doug Hodge from the Southern Forest Experiment Station put out a paper, "Computer Can Choose Sowing Strategies for Containerized Seedlings." In a nutshell, "the sowing strategy with the smallest penalty per cell or penalty per seedling is optimum in the sense that it does the most efficient job of dealing with the problem of blank cells."

The programme they provide does not encompass all factors. In fact, it only considers the nursery problems, not the shipping or field problems. However, it is a start, and is relatively simple.

After we have carefully considered all the pertinent factors, we come up with a rational, economically sound decision. We know exactly the number of seeds per cavity we need to give us the lowest cost per thousand. Then the seeding machine gives us 6% blanks, 14% singles, 50% doubles, 20% triples, and 10% quadruples.

This brings us to the next question. Would it be possible for the seed plant at Angus to sort the seed in such a manner as to attain a very uniform sized batch of seed with over 95% germination? Perhaps we could look at pelletizing the seed, especially black spruce, because pelletizing greatly improves the seeding accuracy and it does not significantly reduce germination.

We should not cut corners with the seeding machine. We need a seeding machine that gives us 99% to 100% seeding accuracy. These machines are available (there is one at Thunder Bay Forest Station), and they need not be the bottleneck in the flat filling, seeding, and gritting line. Also, we need trained personnel to operate and monitor the flat filling, seeding, and gritting greenhouse loading operations.

So what does all this give us? Pelletized seed with 95% germination, an accurate seeding machine, quality personnel, and a thinning operation (double seed each cavity to ensure a minimum of 95% stocking). The initial reaction from the nursery people is, "Hey, that costs money!" Yes, it does; but as far as the taxpayer is concerned, it may be cheaper with reduced shipping and planting costs. This last statement is a "gut feeling"; however, it will be fortified (one hopes) when the programme of Pepper and Hodge is elaborated to include all major possible costs.

XXIII

EVALUATION OF GROWING MEDIA FOR REARING CONTAINERIZED RED PINE AND BLACK SPRUCE SEEDLINGS

II. CHEMICAL ANALYSIS

M.E. Palcic and V.R. Timmer

We reported last year on the comparative growth performance of seedlings of red pine and black spruce grown in nine different soil mixes. Five of these were used operationally (in 1981) at MNR nurseries; three were available as commercially prepared mixes; and one was a peat vermiculite mix used at Glendon Hall. We noted large differences in seedling growth on some of these mixes (Palcic and Timmer, 1982). Since then, we have completed chemical analyses of the substrates and of the plants, and have related these to the growth response of the seedlings in order to identify criteria which may be sensitive indicators of the suitability of peats for containerized tree seedling production. The potting mixes were analyzed by three different methods of analysis which measured total water and ammonium acetate-extractable nutrients, so that we could determine the method most reliable for predicting seedling growth performance on potting mixes.

In the trial with red pine we found that growth (or dry weight) was strongly related to the pH of the growing media at harvest time (Fig. XXIII-1). The commercial mixes Promix and Metromix resulted in the highest pH (7.1 and 6.4), and induced pronounced chlorosis and stunting of the plants (Palcic and Timmer, 1982). It is well known that red pine seedlings are sensitive to the high soil pH; thus we suspected that the growth inhibition may be caused by Fe and P deficiencies. This was supported by the analyses from the seedlings: the content of P and Fe in the shoots was significantly and negatively correlated with the pH of the soil mix (Fig. XXIII-2), indicating that the availability of these nutrients was released with increasing pH of the rooting media.

There were no significant correlations between black spruce growth performance and nutrient levels of the soil mix, suggesting that the growth differences were not associated with nutritional problems. Black spruce is more tolerant to high soil pH, hence the test trees performed better on the commercial mixes as compared to the red pine. However, black spruce seedlings developed poorly on the Midhurst and the Swastika (Dunmore) soil mixes, which contained larger proportions of mineral soils. The greater compaction and poorer aeration associated with the use of these materials may be responsible for the reduced growth.

We correlated nutrient uptake of the seedlings with the nutrient status of the growing media determined by the three analytical techniques (Table XXIII-1). The saturated water extraction is a new test procedure employed at Glendon Hall (Timmer and Parton, 1982) and is considered suitable for greenhouse growing media. Ammonium acetate extraction is usually conducted on mineral soils and estimates the concentration of exchangeable nutrients. Both methods measure only a part (the readily available or soluble fraction) of the total nutrients in the growing media. Total nutrient analysis involves determination of elements in the solution after complete ashing or digesting of the sample, and is commonly performed on organic materials or plant tissues. It can be seen from Table XXIII-1 that water-extractable N, P, Ca and Mg of the soil mixes correlate better with nutrient uptake of red pine than any of the other analytical techniques. This is also apparent for P and Ca in the black spruce trial. Total nutrient analysis of the growing media results in the weakest correlations with seedling nutrient content. These results indicate the superiority of using water-extractable nutrients as predictors of seedling growth in container culture.

References

Palcic, M.E. and V.R. Timmer. 1982. Evaluation of growing media for rearing containerized red pine and black spruce seedlings. Proc. Nurserymen's Meeting, OMNR, Thunder Bay, Ont. June 1982. pp. 38-40.

Timmer, V.R. and W.J. Parton. 1982. Monitoring nutrient status of containerized seedlings. Proc. Nurseryman's Meeting, OMNR, Thunder Bay, Ont. June 1982. pp. 48-58.

Table XXIII-1: Correlation coefficients (r^2) between plant nutrient uptake and soil nutrients estimated by three techniques

	Extractant		Total
	Water	Ammonium Acetate	Analysis
	Red Pine		
Nitrogen	0.57† #	—	0.39*
Phosphorus	0.73†	0.71†	-0.05
Potassium	0.22	0.02	0.33
Calcium	0.79†	0.13	0.32
Magnesium	0.47†	0.37	0.75†
	Black Spruce		
Nitrogen	0.32#	—	-0.11
Phosphorus	0.71†	0.39	-0.12
Potassium	-0.02	0.46*	0.35
Calcium	0.67†	0.45*	0.28
Magnesium	0.22	0.61†	0.50*

† 1% level of significance
* 5% level of significance
# determined as NH_4^+-N for this method

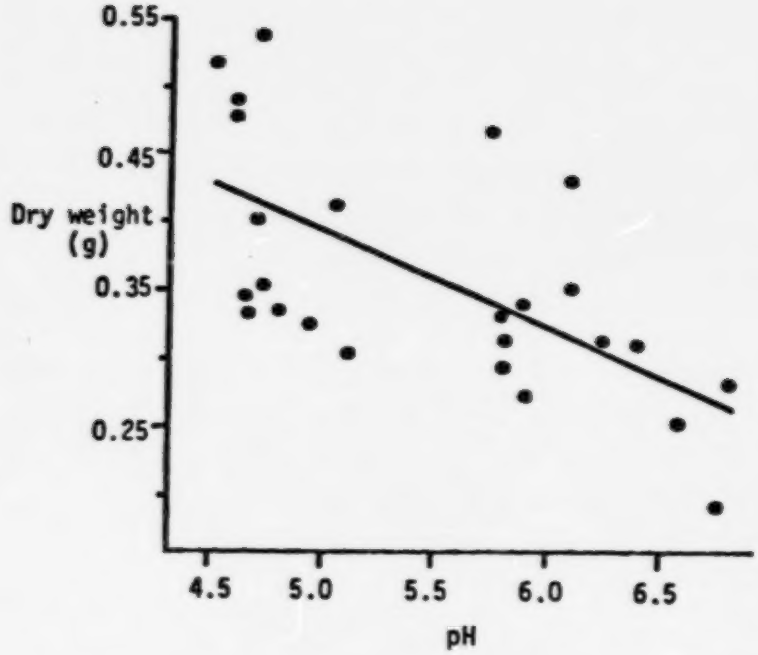


Fig. XXIII-1: Relationship between total dry weight of 16-week-old red pine and pH of the soil mix (r=-0.64)

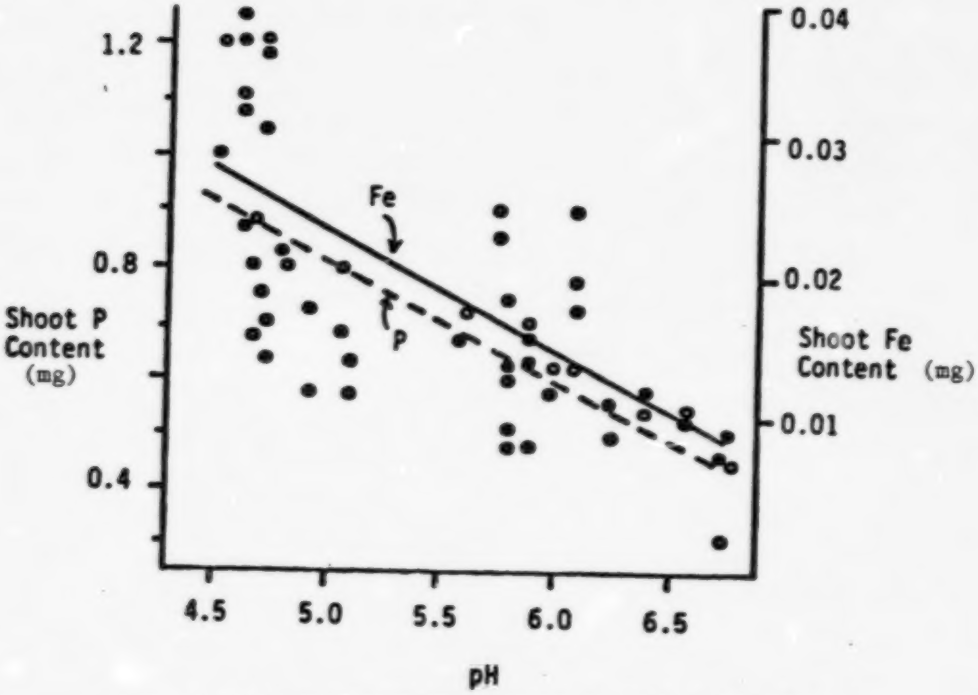


Fig. XXIII-2: Relationship between Fe and P content in red pine shoots and pH of the soil mix (r=-0.72 for both)

XXIV

MICRONUTRIENT DEFICIENCY IN BLACK SPRUCE NURSERY STOCK?

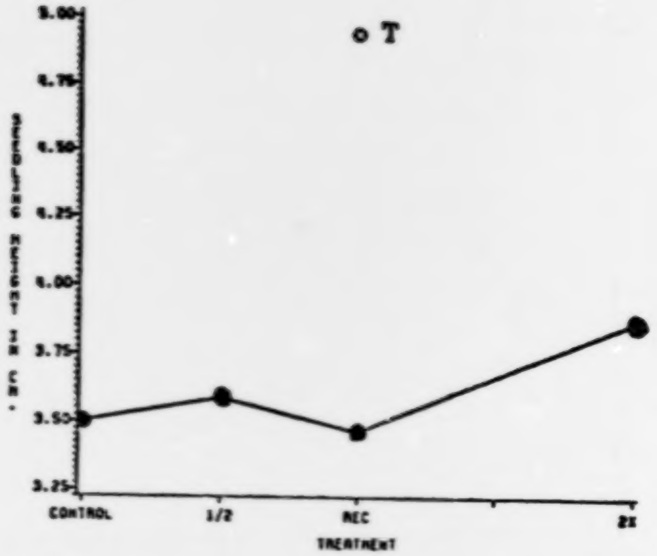
W.J. Parton and V.R. Timmer

One of the production goals at Midhurst nursery is to rear a 1+0 black spruce suitable for spring transplanting. This would involve producing a much larger than average seedling in the first year. We initiated small-scale fertilization trials to assess whether supplemental fertilization would accelerate first-year seedling development. We tested a highly soluble "Finish" (NPK) nutrient solution, which was applied at 0, 0.5, 1, and 2 times the recommended rate, in addition to the regular fertilization regime of the nursery.

Initial results after one season (1981) showed little growth response in black spruce receiving above-normal levels of NPK fertilizer. A similar lack of response to extra top-dressings of N, P, and K had also been noted with red pine, white pine, and white spruce at the Orono nursery (Bunting, 1982, pers. comm.). These results suggested that the macronutrient status of these nursery soils was effectively maintained at the optimum by the regular fertilization programme prescribed by main office staff.

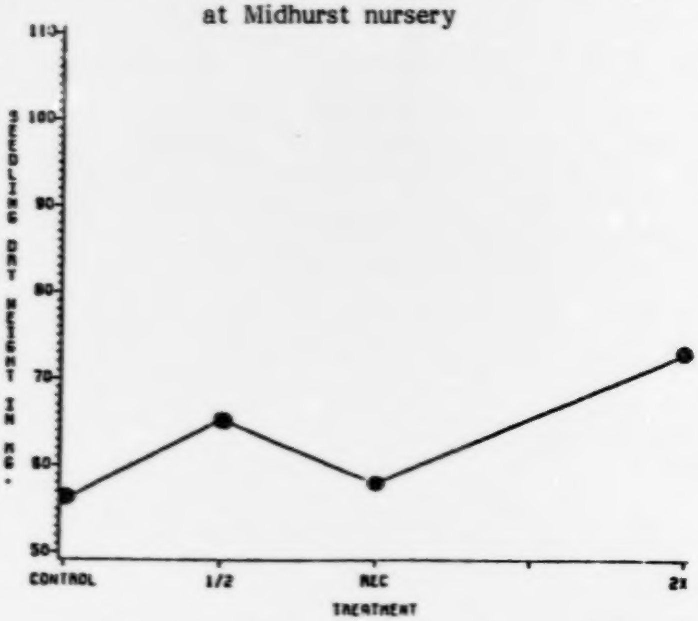
However, prolonged and continued application of macronutrients at high levels may well induce deficiencies or imbalance of micronutrients in soils or tree crops. Hence, we decided to duplicate the experiment in the next growing season (1982) with an extra treatment combining the Finish solution with a foliar spray of a complete micronutrient mix. The results from this trial were surprising. By fall, height growth of the seedlings (Fig. XXIV-1) receiving both micronutrients and Finish solution demonstrated a 43% increase over the control (normal fertilization). The response in dry weight was 83% greater than the control (Fig. XXIV-2). Seedling mortality (Fig. XXIV-3) was increased substantially by the higher dosages of nutrient solution, except for the treatment associated with the micronutrients. Thus, a two-time foliar spray of trace elements over the summer improved both growth and survival of black spruce seedlings. We failed, however, to detect significant responses in an identical trial established in white spruce seed beds, indicating that white spruce may have a different micronutrient requirement than black spruce.

These responses demonstrate the benefits of incorporating trace elements in the fertilization of black spruce nursery stock. We were unable to single out the specific micronutrient responsible for the additional growth response because of the constraints of the experimental design, although we suspect, based on comparative foliar analyses of responsive and nonresponsive seedlings, that boron and manganese may be involved. We are now conducting more elaborate fertilizer experiments at the Midhurst nursery to identify the micronutrient(s) contributing to the improvement in growth of black spruce seedlings.



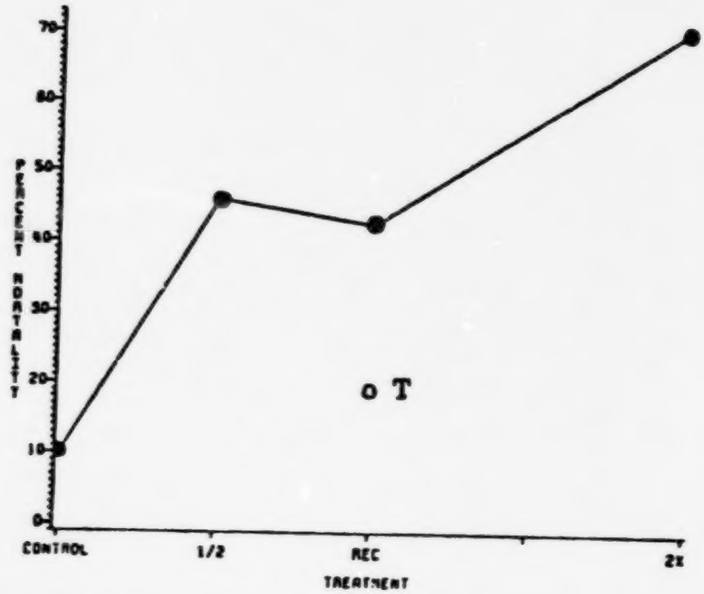
Height of 1+0 black spruce supplemented with increasing application of macronutrient solution (0, 1/2, 1, and 2 times recommended rate) above-normal fertilization regime. Open circle (T) marks additional trace element (micronutrient) treatment.

Fig. XXIV-1: Fertility trial in 1+0 black spruce (height) at Midhurst nursery



Dry weight of 1+0 black spruce supplemented with increasing application of macronutrient solution (0, 1/2, 1, and 2 times recommended rate) above-normal fertilization regime. Open circle (T) marks additional trace element (micronutrient) treatment.

Fig. XXIV-2: Fertility trial in 1+0 black spruce (dry weight) at Midhurst nursery



Mortality of 1+0 black spruce supplemented with increasing application of macronutrient solution (0, 1/2, 1, and 2 times recommended rate) above-normal fertilization regime. Open circle (T) marks additional trace elements (micronutrients) treatment.

Fig. XXIV-3: Fertility trial in 1+0 black spruce (mortality) at Midhurst nursery

XXV

INCIDENCE OF MULTI-LEADERING UNDER VARIOUS CULTURAL PRACTICES

J. Ensing, C. McLeod, and G. Hofstra

For the past three years, our work on multiple leadering (ML) has had two major emphases: (i) a survey of the incidence of multiple leadering at OMNR nurseries, and (ii) an investigation of the causes of ML in nursery stock. Because the incidence of ML is apparently higher in white spruce, our research has been largely conducted on this species, with only some work done on black spruce. Last year, at the nurserymen's annual meeting, we discussed some of the cultural practices which may lead to ML, as well as a number of environmental factors which do not seem to induce ML. Our experimental work of last year could be summarized by stating that at the northern nurseries low temperature injury appears to cause the significant levels of ML frequently observed. At southern nurseries, especially Midhurst, unknown factors besides low temperature, disease, or chemical residue appear to be important. There is general concern not only about the causes of spruce multi-leadering in nursery beds, but also about culling standards in relation to ML. Currently ML trees are culled; however, it is often pointed out that it is not known if ML seedlings stay ML after they are outplanted. This would appear to make the culling standards unacceptably arbitrary.

I will attempt to discuss our observation and research results in a context significant to nurserymen.

Incidence of Multi-Leadering at Ontario Nurseries

We now have three years of data on the incidence of ML at various Ontario nurseries. Overall, the rates of ML have been lower in the previous three years than was apparently common before our study began. Gross (1983) has reported that cull rates have commonly reached 40% and occasionally as high as 60%. The incidence of ML during our three-year study has rarely exceeded 30%.

The trend in ML rates of 2+0 white spruce at Ontario nurseries from 1980 to 1982 is demonstrated in Fig. XXV-1. The Midhurst nursery generally has the higher rates of ML in 2+0 white spruce. Orono and St. Williams nurseries have the lowest rate of ML. Swastika has variable rates of ML, indicating the result of observed winter injury. Multi-leadering has increased steadily at Midhurst, Kemptville, and Thunder Bay.

The rate of ML in 3+0 white spruce from 1980 to 1982 is shown in Fig. XXV-2. Midhurst has high rates of ML in 3+0 stock, as do most of the other nurseries, although it is quite variable from year to year. It is interesting to note that the ML trends at Midhurst and Kemptville are the same for both age-classes of spruce.

The incidence of ML in black spruce from 1980 to 1982 is indicated in Fig. XXV-3. Only 2+0 data are available because there is no 3+0 black spruce grown at our nursery. The data do demonstrate that ML rates in black spruce do not always reach the levels seen in white spruce.

Incidence of Multiple Leadering of Spruce Across Canada

White spruce (2+0) was also sampled from nurseries across Canada. The histogram in Fig. XXV-4 shows the average rates of ML of two seedlots from each nursery. In addition to several Ontario nurseries, high rates of ML (greater than 25%) were also observed in Alberta, Saskatchewan, Manitoba, and New Brunswick. It is obvious that ML is not a problem exclusive to Ontario. Alberta views its rates of ML in spruce as considerable; Saskatchewan expressed interest in our work; Juniper Nursery in New Brunswick is also greatly concerned about the high rates of ML occurring there.

The Effect of Multiple Leadering on Growth

Culls of white spruce were collected at tree lifting in Ontario nurseries. Height, root collar diameter, and dry weights were measured and compared with normal trees within the same compartment. Table XXV-1 demonstrates that a large proportion of trees culled are multiple-leadered and that ML trees are smaller than normal trees in terms of height at both Midhurst and St. Williams. Table XXV-2 summarizes the root collar diameters and heights of multiple-leadered and normal trees at Ontario nurseries. Although heights are consistently less in multiple-leadered stock, it is important to notice that shoot weights and root collar diameters do not differ from those of normal trees.

Outplanting Trial at Midhurst

An outplanting trial was established at the Midhurst nursery in 1980. Equal numbers of single, double, and multi-leadered white spruce were planted. Assessment in the spring of 1983 (Table XXV-3) showed that 90% of trees planted normal remained so; 61% of trees planted double remained double; and only 28% of trees planted ML remained ML. Fifty-one per cent of all trees planted in 1980 were normal in 1983. Tree heights did not vary greatly.

Experimental Studies

Experimental studies in 1982 focused on frost hardiness, herbicide complication, light intensity, and nutrition.

Frost Hardiness: As reported last year, seedlings that have normal buds by the end of the growing season may multi-leader the following spring. Fall frosts, winter injury, and late spring frosts are the most frequent causes of this type of ML, especially in northern nurseries (Table XXV-4). Two early fall frosts occurred in 1982 at Dryden, resulting in a 90% incidence of dead buds on 1+0 white spruce seedlings; 1+0 seedlots were more severely affected than 2+0 stock.

Herbicide Application: A herbicide trial was conducted at Midhurst in two 1+0 white spruce compartments. Table XXV-5 shows the effect of normal herbicide applications during the growing season on the incidence of bud abnormalities. No differences were observed between plots receiving herbicides and those from which herbicides were excluded.

Light Intensity: Both light intensity and high temperature have an effect on apical dominance. High light encourages lateral dominance in many plants. High temperatures can reduce the uptake of some of the micronutrients known to be required for proper growth of the apex (e.g., boron). At some nurseries, shades are extensively used during the 1+0 year; in other nurseries, shades are removed after seedlings have germinated. At Midhurst it seemed that over the years ML increased as the use of shades decreased. Therefore, a study was conducted to determine whether shading had any impact on the incidence of ML. Table XXV-6 shows the effect of shading on ML and growth. No differences were observed between treatments in 1982, indicating that shading was not a factor in ML. However, much of the summer of 1982 was cool and overcast, with August temperatures 2.1°C below normal. These factors may have precluded the effect of shades on growth of 1+0 white spruce; this study will therefore be repeated in 1983.

Nutrition: Several studies were conducted on the impact of nutrition on multiple leadering. A number of nutrients are known to be important for proper development of apices and apical dominance. These include calcium, boron, and nitrogen. Table XXV-7 summarizes the results of a trial to determine whether any of these are a factor in ML. Specific nutrients were applied individually (boron as spray, frit, or soil drench; calcium as calcium sulfate; nitrogen as plus or minus field rate). Micronutrients were also added as a complete mix from two (frit, foliar spray) sources. The addition of calcium, boron, and micronutrients had no effect on the incidence of ML, whereas the deletion of field N significantly reduced the rate of ML.

Two fertilizer trials at Orono were also rated for the effects of N application in the incidence of abnormal buds and ML. Increasing concentrations of N resulted in an increase in the formation of abnormal buds on both 1+0 and 2+0 white spruce, with less effect, during the experimental year, on ML (Tables XXV-8 and XXV-9).

Our work on nutrition indicates that nitrogen application may be a factor when inducing ML. Nitrogen trials will be continued in 1983.

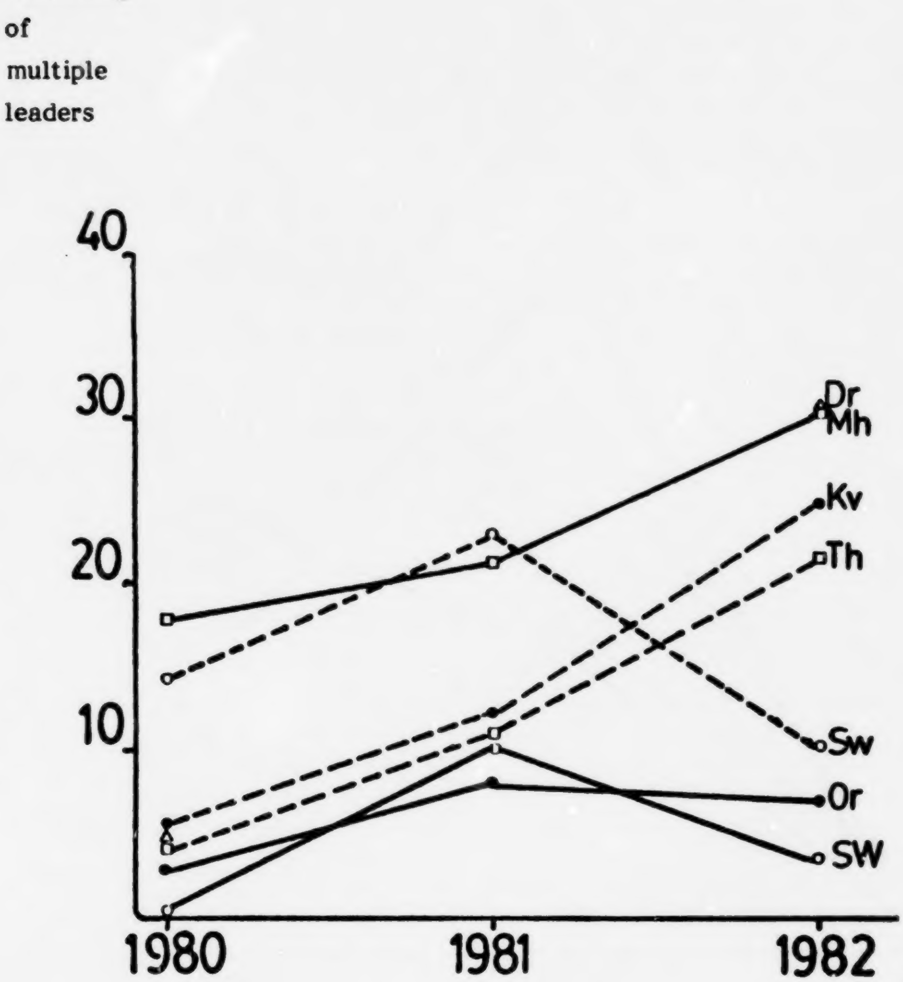


Fig. XXV-1: Percentage of multi-leadering
in 2+0 white spruce (1980-82)

Dr - Dryden Mh - Midhurst Kv - Kemptville Th - Thunder Bay
Sw - Swastika Or - Orono SW - St. Williams

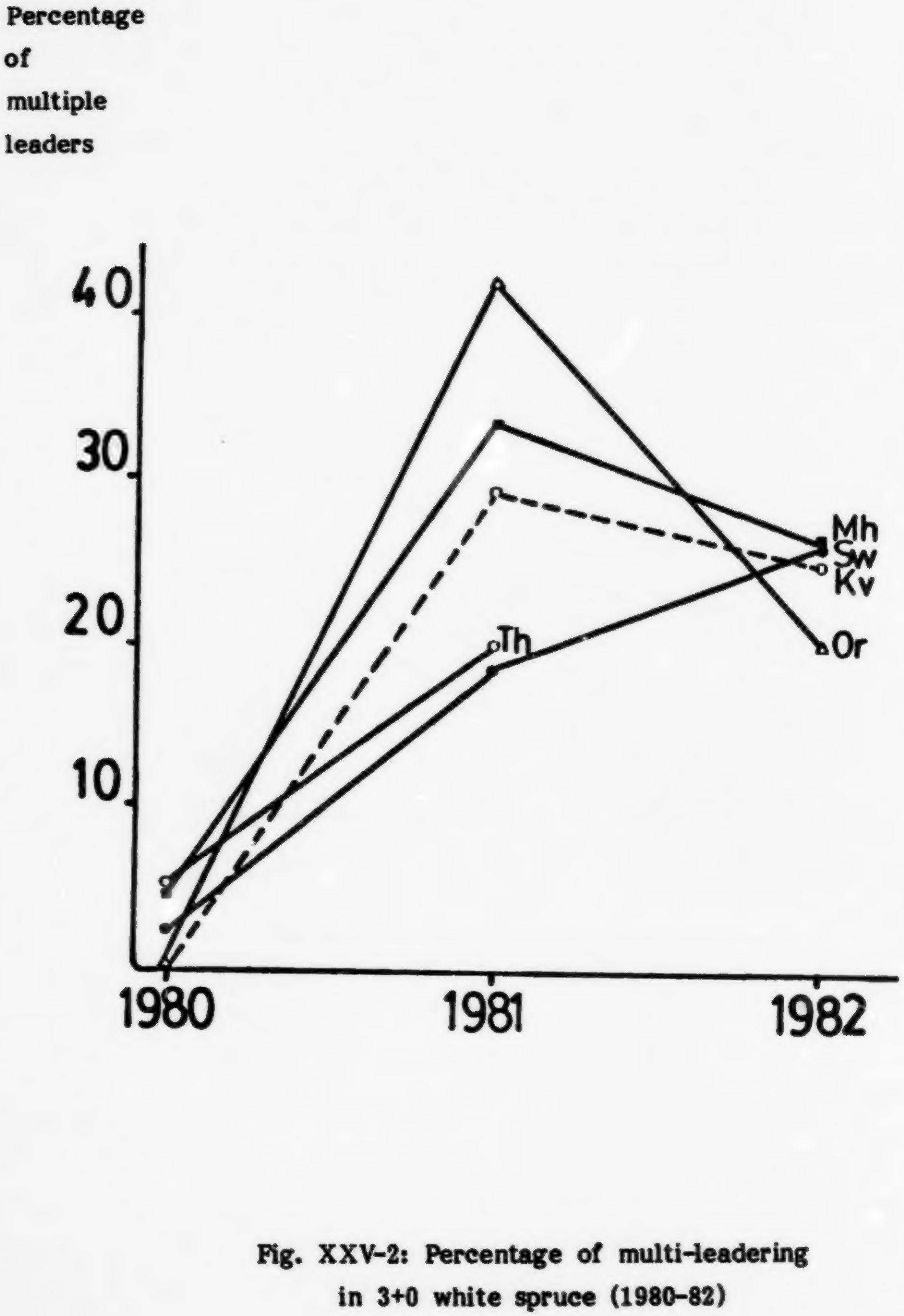


Fig. XXV-2: Percentage of multi-leadering in 3+0 white spruce (1980-82)

Mh - Midhurst Sw - Swastika Kv - Kemptville Or - Orono
Th - Thunder Bay

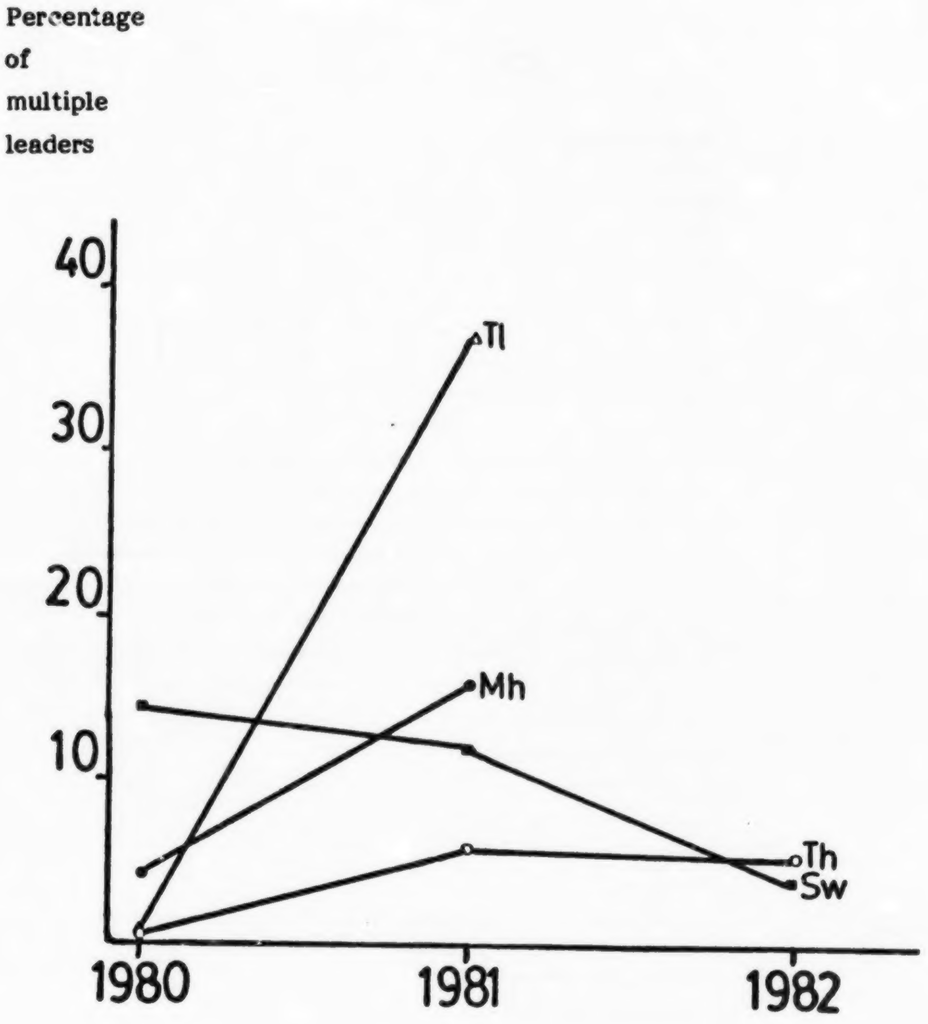


Fig. XXV-3: Percentage of multi-leadering in 2+0 black spruce (1980-82)

Tl - Thessalon Mh - Midhurst Th - Thunder Bay Sw - Swastika

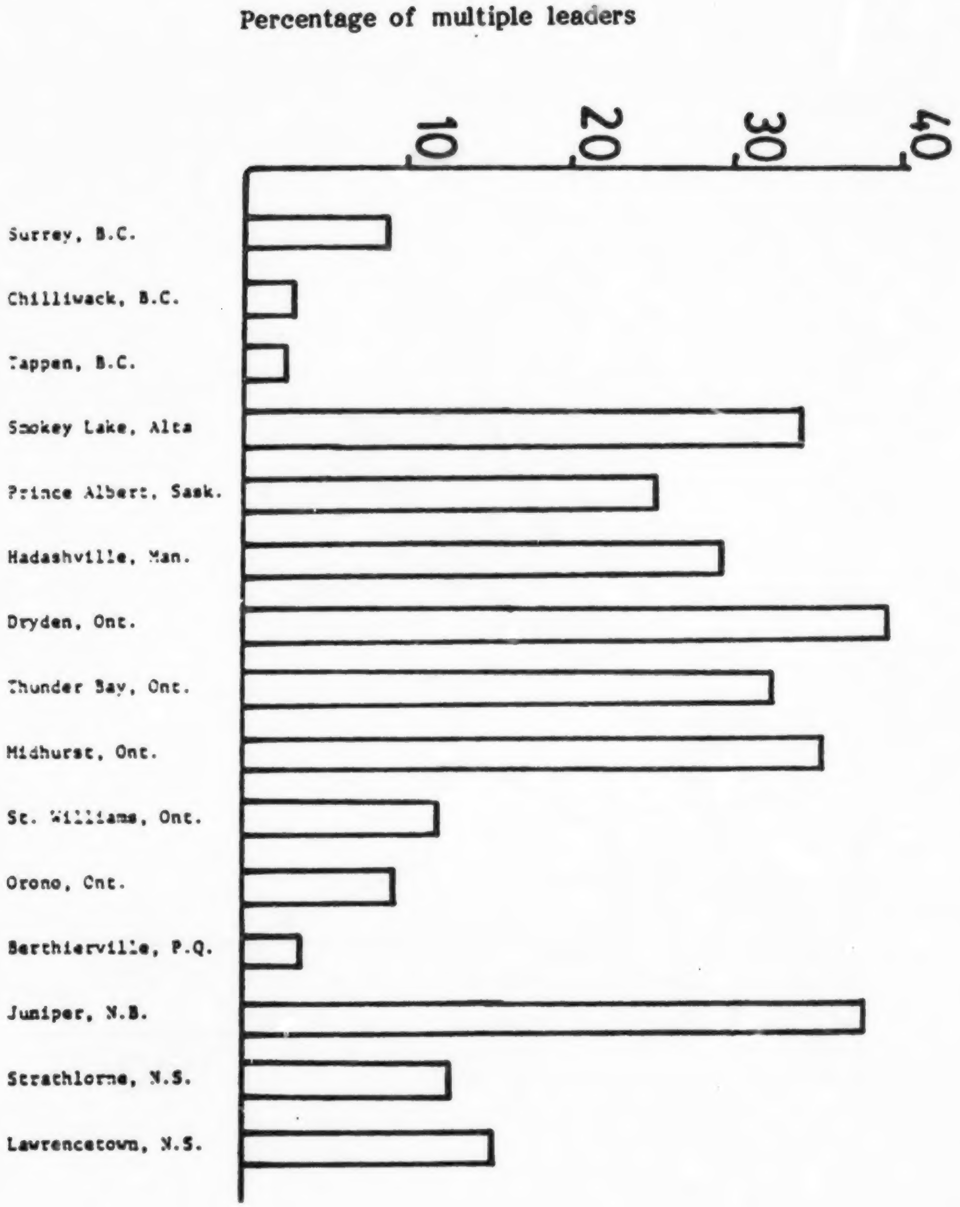


Fig. XXV-4: Multiple leader rate of 2+0 white spruce at Canadian nurseries (1982)

Table XXV-1: A comparison of cull percentage and seedling height at three Ontario nurseries

Nursery	Percentage of ML in Cpt.	Percentage of ML in Cull	ML Seedlings Height (cm)	Normal Seedlings Height (cm)
Midhurst	27.2 ± 6.1	44 ± 8	19.6 ± 1.6	26.9 ± 1.8
St. Williams	10.1 ± 16.5	13 ± 9	14.1 ± 1.0	18.6 ± 1.5
Orono	20.0 ± 3.0	19 ± 8	10.3 ± 2.0	—

Table XXV-2: A comparison of the heights, root collar diameters, and shoot dry weights of the multiple-leadered trees in Ontario nurseries (3+0 white spruce)

Nursery		Height (cm)	Diameter (mm)	Dry Weight (100 trees) (g)
Kemptville	N*	13.2 + 1.5	2.3 + 0.1	
	ML	10.8 + 1.0	2.3 + 0.1	
Midhurst	N	13.5 + 1.8	2.8 + 0.2	164 + 9.6
	NL	10.7 + 1.4	2.7 + 0.1	168 + 13.0
Orono	N	13.8 + 1.6	2.6 + 0.2	
	ML	10.7 + 1.9	2.3 + 0.5	
St. Williams	N	18.6 + 1.6	2.9 + 0.4	
	ML	14.8 + 2.8	3.3 + 0.3	
Thunder Bay	N	8.9 + 1.1	1.3 + 0.2	47 + 4.8
	ML	6.4 + 0.7	1.2 - 0.1	37 + 18.5
Dryden	N	10.0 + 1.0	1.7 + 0.2	30 - 3.8
	ML	8.5 + 0.9	1.7 + 0.2	31 + 2.0
Total	N	13.0 + 3.4	2.3 + 0.6	80 - 7.3
	ML	10.3 + 2.8	2.3 + 0.7	79 + 7.7

* N = normal; ML = multiple leadered

Table XXV-3: 1983 status of multi-leadered outplanting trial

Original Status (1980)		Present Status Normal	 Double Leadered	 Multi-leadered
Normal	percentage	90 (100)*	8 (0)	2 (0)
	height (cm)	41.4 ± 7.4	37.9 ± 8.1	46.9 ± 10.0
Double leadered	percentage	36 (0)	61 (100)	3 (0)
	height (cm)	42.4 ± 7.4	39.4 ± 6.6	38.7 ± 8.8
Multi-leadered	percentage	28 (0)	51 (0)	21 (100)
	height (cm)	41.7 ± 7.2	38.3 ± 5.8	38.3 ± 5.5
Overall average	percentage	51.2 (33.2)	40 (32.5)	8 (34.3)
	height (cm)	41.7 ± 7.0	38.8 ± 6.0	38.9 ± 6.0

* Bracketed value = original status (1980)

Table XXV-4: The incidence of dead terminals
at three Northern Ontario nurseries

Nursery	Dead Terminals (%) April 1981	 April 1982	 October 1982
Dryden			
1981 Sb 2+0	41	0.7	
1982 Sb 2+0		30	45
1982 Sb 1+0			76
1982 Sw 2+0		17	16
1982 Sw 1+0			90
Swastika	July 1981		
1981 Sb 2+0	11.2		
1982 Sb 1+0			6
1981 Sw 2+0	1.0		
1982 Sw 1+0			70
Thunder Bay			
1982 Sb 1+0			3
1982 Sw 1+0			23

Table XXV-5: The effect of herbicide on 1+0 white spruce at Midhurst

Compt.	Treatment	Bud Condition (%)		
		Normal	Abnormal	Other
A43	herbicide*	78	13	9
	no herbicide †	75	11	14
A10	herbicide*	69	18	12
	no herbicide†	75	12	13

* Dacthal when full sown

† AWK, gesagard

Table XXV-6: The effect of shading on 1+0 white spruce at Midhurst

Compt.	Treatment	M_2 (%)	M_3 (%)	AB (%)	DW (g)	H (mm)	D (mm)
A43	unshaded	10.5	1.7	13.0	11.42	42.9	0.98
	shaded	10.8	1.5	13.8	8.67	40.9	0.95

Table XXV-7: The effect of specific nutrient supplements
on the incidence of abnormal buds and ML (Midhurst, SW 1+0)

Compt.	Treatment	M_2 (%)	M_3 (%)	AB (%)
A43	Control	14.2a	2.7a	7.3ab
	Minus-N	5.5b	1.8a	4.3b
	Calcium	13.3a	3.2a	6.2ab
	Boric acid (spray)	10.3ab	2.2a	6.3ab
	Boron frit	11.2a	2.8a	6.7ab
	Borate (soil)	10.7ab	2.0a	7.0ab
	Ca + Borate	13.7a	2.8a	5.3ab
	Micronutrient frit	9.3ab	2.5a	8.0a
	Micronutrient (spray)	9.3ab	2.0a	8.0a

Values in a given column followed by the same letter are not significantly different (P = 0.05, analysed by ANOVA and protected LSD)

Table XXV-8: Fertilizer trial at Orono on one-year-old white spruce (Cpt. S2-6) sampled in the fall, 1982

Treatment	M_2* (%)	ab† (%)
0 N	1.6	1.0
1/2 N	1.6	2.0
1 N	3.0	6.0
2 N	3.6	9.4

* M_2 — double leadered
† ab — abnormal buds

Table XXV-9: Fertilizer trial at Orono on two-year-old white spruce (Cpt. S2-1) sampled in the fall, 1982

Treatment	Height (mm)	M_2* (%)	M_3# (%)	ab† (%)
0 N	111	12	5	6.2
1/2 N	122	16	3	8.7
1 N	125	13	4	10.8
2 N	135	14	2	10.0

* M_2 — double leadered
# M_3 — multiple leadered
† ab — abnormal buds

6 reps/treatment
40 seedlings/rep

Appendix

AGENDA

Monday, June 13, 1983

7:00 p.m.	Conference registration at Kemptville College of Agriculture Technology (KCAT); and attitude adjustment.

Tuesday, June 14, 1983

8:30 a.m.	Conference registration (cont.) Nursery Forestry Centre	
9:00 a.m.	Opening remarks	A.J. Campbell, Nursery Superintendent J.R. Oatway, Regional Director P.E. Anslow, Regional Forester
9:30 a.m.	Agenda and announcements	A.J. Campbell, Conference Chairman
9:40 a.m.	Coffee break	
10:00 a.m.	Hybrid poplar production — session introduction	Tony Prinsen
10:05 a.m.	Proceed to stoolbed compartment	
10:15 a.m.	Hybrid poplar production	A.J. Campbell
11:15 a.m.	Proceed to shipping centre	
11:30 a.m.	Processing/storage/shipping	Pam Smith
12:00 noon	Lunch break	
1:00 p.m.	Soil amendments and seedling protection — session introduction	Bill Reitsma
1:05 p.m.	Proceed to compartment C-12	
1:15 p.m.	Soil pH	Vic Timmer
2:00 p.m.	Proceed to fertilizer building	
2:10 p.m.	Applying soil amendments	Grant Leeder
2:30 p.m.	Coffee break	
2:45 p.m.	Proceed to chemical building	
2:50 p.m.	Herbicides and application equipment	Charlie Waywell
3:20 p.m.	Proceed to weeding operation	
3:30 p.m.	Piecework hand weeding	Bob Klapprat
4:00 p.m.	Equipment demonstration and trade exhibits	Grant Leeder
5:00 p.m.	Return to KCAT	
7:30 p.m.	Informal session and trade exhibit	Liisa Raitanen

Wednesday, June 15

8:30 a.m.	Management considerations — session introduction	Tony Vandenberg
8:35 a.m.	Microcomputers	John Findeis
9:45 a.m.	Coffee break	
10:00 a.m.	Cost accounting and coding	Dolf Wynia
10:20 a.m.	Growth prediction	Bill Bunting
11:00 a.m.	Contracting	Antoinette Wells
11:20 a.m.	Quality control in tree lifting	Grant Leeder

11:40 a.m.	Managing under constraints	Dave MacNaughtan
11:50 a.m.	Lunch "to go"; regional tour of Cornwall, Brockville, and Carleton Place Districts	
7:00 p.m.	Dinner in Ottawa	
8:00 p.m.	Return to KCAT	
12:00 p.m.	Alternate return to KCAT	

Thursday, June 16

8:30 a.m.	Containerized tree seedling production — session introduction	Ron VandenTillaart
8:35 a.m.	Provincial situation report	Ken Reese
9:00 a.m.	Contracting container stock production	Antoinette Wells
9:20 a.m.	Acclimatizing and overwintering	Steve Colombo
9:40 a.m.	Accelerated transplants	Randy Morrison
10:00 a.m.	Coffee break	
10:15 a.m.	Proceed to greenhouse	
10:20 a.m.	The multipot system	Bob Klapprat
12:00 noon	Lunch break	
1:00 p.m.	Irrigation — session introduction	Hannah Fydenchuk
1:05 p.m.	Atmospheric demand for evapotranspiration — nursery irrigation schedule	Chris Papadopol
1:35 p.m.	Proceed to pumphouse	
1:50 p.m.	The new irrigation system	Dave MacNaughtan
2:15 p.m.	Proceed to compartment	
2:30 p.m.	Moisture monitoring	Bill Bunting, Liisa Raitanen
3:00 p.m.	Coffee break	
3:15 p.m.	Proceed to compartment	
3:30 p.m.	Root wrenching/root pruning	Alf Campbell
4:15 p.m.	Growth control	Bill Bunting
5:00 p.m.	Return to KCAT	
6:00 p.m.	Banquet	

Friday, June 17

8:30 a.m.	Seed-improvement/Production/Utilization — session introduction	Pam Smith
8:35 a.m.	Tree improvement in the Eastern Region	Ken Eng
9:00 a.m.	Seed extraction and dispatch	Brian Swaile
9:30 a.m.	Seed utilization: Bare-root	Carl Mansfield
	C.T.S.	John Dewitt
10:15 a.m.	Coffee break	
10:30 a.m.	Proceed to tree improvement area	
10:45 a.m.	Poplar tree improvement	Brian Barkley
11:30 a.m.	Return to Forestry Centre	
11:40 a.m.	Wind-up	Ken Reese
12:00 noon	Adjournment	Alf Campbell

ATTENDANCE

Name	Location
BARTY, Brenda	Swastika
BENNETT, Ken	Maple, OTIFBI
BORCZON, Ed	Richmond Hill
BRIAND, Judy	Thessalon
BUNTING, Bill	Nu Tech Services, Box 424, Orono
CAMERON, Richard	Swastika
CAMPBELL, Alf	Kemptville
CARLETON, John	Chapleau
CARRIER, Andre	Gogama
COLOMBO, Steve	Maple, OTIFBI
CREASEY, Kim	Angus
DEWITT, John	Thunder Bay
ENG, Ken	Richmond Hill
ENSING, John	University of Guelph
FINDEIS, John	Financial Planning Group, Toronto
FYDENCHUK, Hannah	Kemptville
GASBARRI, John	Richmond Hill
GOWER, Bill	Gogama
GRIFFITHS, Susan	Hakmet
GROVES, Rid	Midhurst
HARVEY, Eileen	Lakehead University, Thunder Bay
HARVEY, Mark	Lakehead University, Thunder Bay
HUSK, Clare	Blind River
JOHNSTON, Pud	London
KEATING, Craig	Maple, OTIFBI
KLAPPRAT, Bob	Kemptville
LEEDER, Grant	Kemptville
LEVEILLE, Gilbert	Swastika
MacNAUGHTAN, Dave	Kemptville
MANSFIELD, Carl	Midhurst
McLEOD, Cathy	University of Guelph
McLEOD, Glenn	St. Williams
METCALFE, Bob	Can Am Containers
MILLER, Bruce	Can Am Containers
MORRISON, Randy	Swastika
MULANER, Dave	Can Am Containers
MYLAND, Terry	Dryden
NOLAN, John	London
ODLUM, Kerry	Maple, OTIFBI
PALCIC, Mayda	University of Toronto
PAPADOPOL, Chris	Maple, OTIFBI
PARTON, John	University of Toronto
PATERSON, John	Maple, OTIFBI
PHILLION, B.	Orono
POLHILL, Brian	Dryden
POSTMA, Mike	St. Williams
RACEY, Gerry	Maple, OTIFBI

RAITANEN, Liisa	Kemptville
REESE, Ken	Toronto
REITSMA, Bill	Kemptville
SADREIKA, Vic	Toronto
SEABROOK, Ivan	Thessalon
SMITH, Pam	Kemptville
SNIVELY, Gord	St. Williams
SWAILE, Brian	Angus
THAYER, Ron	St. Williams
TIEMANN, Henry	Toronto
TIMM, Otto	Timm Enterprises
TIMMER, Vic	University of Toronto
ULMONEN, Ulla	Hakmet
VANDENBERG, Tony	Kemptville
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WELLS, Antoinette	Toronto
WYNIA, Dolf	Thunder Bay
WYNN, John	Canadian Forestry Equipment